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THE SOIL SCIENCE SOCIETY OF FLORIDA

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Thirteenth Annual Meeting of the Society
University of Florida
Gainesville
January 14, 15 and 16, 1954

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1954

Ernest L. Spencer	President
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Nathan Gammon, Jr.	Member Executive Committee
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Retiring Officers listed on page 177

ACKNOWLEDGMENTS

It is the desire of the Executive Committee of the Society to take this opportunity of thanking the Officials of the University of Florida for their generous permission to use the Campus and its many excellent facilities for the Annual (1953) meetings. More particularly do we find ourselves indebted to Provost Reitz, Directors Fifield and Clayton and Dean Noble for the helpful interest they showed throughout the course of these meetings.

Likewise it is desired to express our sincere gratitude to Dr. Selman A. Waksman, eminent director of the Institute of Microbiology at Rutgers University, the State University of New Jersey, for his fine leadership of the Thursday evening symposium on the Place of Antibiotics in Agriculture, with which the meetings were opened this year and which dealt first with the source and isolation of these marvelous chemical entities and their beneficiations to humans, then plants and then animals; to Dr. H. Rex Thomas, Plant Pathologist of the U. S. Department of Agriculture, Washington, D. C., for the distinguished part he took in this highly technical program as it concerned plant health and growth, on a very short notice and to our own Dr. T. J. Cunha, Head of Florida's Department of Animal Husbandry and Nutrition in the College of Agriculture for his comprehensive closing of the discussion by outlining known benefits to animals.

Finally, the Executive Committee would extend its very best thanks to Drs. Hammond and Blue and the members of their respective committees for the fine job they did in making arrangements for the meetings including the excellent and thoughtful cooperation of the University Lecture Series in connection with the Symposium on Antibiotics and for the annual banquet which was held in the Student Service Center.

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JOSEPH HILLIS MILLER

1899-1953

DEDICATION

Born on a farm near Front Royal, Virginia, in 1899, Joseph Hillis Miller attained national recognition in education during his energetic and interesting life of 54 years. In preparation for his work he studied at Randolph-Macon Academy, University of Richmond, University of Virginia, and Columbia University. He earned the Bachelor of Arts degree at Richmond, the Master of Arts at Virginia, and the Doctor of Philosophy degree at Columbia. He was awarded the Doctor of Literature degree by Keuka College and the Doctor of Laws degree by Alfred University.

Before coming to Florida he served as instructor in psychology at William and Mary, dean and assistant professor of psychology at Bucknell, president of Keuka College, and associate commissioner of education for the State of New York.

Assuming the presidency of the University of Florida soon after the end of World War II, Dr. Miller immediately began a program of work and activity that was to culminate in notable growth of the institution and, for himself and to the sorrow of all who knew him, the end of his life. With initiative and imagination he worked to solve the problems of inadequate housing and facilities for students, insufficient staff for teaching and research, and inadequate equipment for research. He was catholic in his interests, and he delved earnestly into all things pertaining to the University of Florida. While his education and training were primarily confined to philosophy, psychology and the arts, he took an active interest in Agriculture and all the other broad fields of endeavor in the University and the State. He worked tirelessly and persistently for the University of Florida. Under his leadership, the institution's size, achievements, and service rose to the highest peak in its history.

He was greatly interested in Florida Agriculture, and he was intensely proud of the work of the Agricultural Experiment Stations, the College of Agriculture, and the Agricultural Extension Service. He recognized the importance of research in soils and other phases of Florida agriculture, and he gave full support to scientists in these fields.

Never was a man busier nor more absorbed in his work. His dream and the goal which he sought for the University dominated his every effort. Physical fatigue and illness he ignored as he responded to the impelling force of his plans and aspirations for the institution. The reckoning came after six years of such high hopes and such long, hard work, but not until he had left his firm and beneficent imprint upon the University and State of Florida.

HONORARY LIFE MEMBERS

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Winogradsky, Dr. Sergei N., Institute Pasteur, Brie-Comte-Robert, France *

Institut Pasteur**

25, RUE DU DOCTEUR ROUX

Paris, le November 19th, 1953

Dr. Selman A. Waksman
New Jersey Agricultural Expt. Station
New Brunswick, N. J.

My dear Dr. Waksman:

I was glad to receive your lines and to learn that everything is well with you. My own years—today is my 96th birthday—have forced me to limit greatly my activities in all directions. However, I keep well, and my interests in science and in life have not diminished in the least.

There appeared recently in the Annales my small paper "On the Classification of Bacteria," which you no doubt have received. In it I come to the conclusion that there cannot be any scientific classification of bacteria according to the system of Linneus, since the correct classification, namely, the one accepted in botany and zoology, is based on the origin of the species, therefore on paleontology, of which bacteriology cannot take advantage. It would be sufficient to separate and characterize well the type species which have played an important role in bacteri-

* A note from Dr. Winogradsky's daughter, Helen, gives us the simple facts of his death and burial. "My father passed away in the morning of February 24th of this year, after a long and very painful illness. He was buried on February 26th in our family vault, in the church yard of Brie-Comte-Robert, the village where his laboratory—the annex of the Institut Pasteur—was situated, and where he had he had worked since he had come to France, and almost to his end."

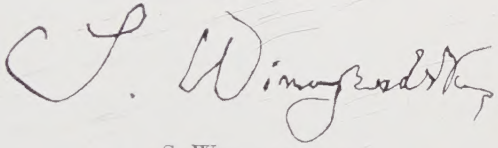
** A letter written on his 96th birthday which is reproduced with the permission of Dr. Waksman should be an inspiration to anyone, anywhere, at any time, who is interested in Science in any form.

ological processes and to group around them, based upon morphological and physiological characteristics, the closely related forms which would thus represent ecological varieties and not independent species. It is sufficient simply to number them, thus avoiding the problem of finding Latin surnames.

My book is being translated and published in Moscow and in Warsaw (in the Polish language). Imshenetzki and the Russian Academy have been corresponding with me for the last two or three years. They promised that copies would arrive not later than July, but naturally they have not yet arrived.

Whether I will live long enough to see you again I doubt, but I still hope. I am sending my most sincere greetings to your constant friend and wife Mme. Deborah.

Yours sincerely,



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SYMPOSIUM: THE PLACE OF ANTIBIOTICS IN AGRICULTURE

ANTIBIOTICS, A NEW FIELD OF SCIENCE AND APPLICATION, AND SOME OF THE RESULTING PROBLEMS

SELMAN A. WAKSMAN *

INTRODUCTION

The introduction of antibiotics, during the past decade and a half for the treatment of infectious diseases has resulted in a remarkable revolution in medical science and in medical practice. Diseases that were formerly believed to be incurable are now being treated successfully. Epidemics that formerly decimated a large part of the population of an infected area can now be prevented and eradicated. Many of the diseases that formerly took a heavy toll both of children and of adults are now being controlled. Gone are the dangers of diphtheria and whooping cough, of pneumonia and typhus fever, of typhoid and plague, of intestinal diseases and many of the respiratory diseases, of venereal diseases and of blood stream infections. Even tuberculosis, formerly the "Great White Plague," which was responsible for the killing of a large percentage of the population at the prime of its youth, is now also on the way out.

All this has resulted in a far greater survival of the younger age groups than has ever been thought possible and in a great prolongation of the average life span of man. There has been a remarkable reduction in both mortality and morbidity. Simultaneously, however, this effect upon the survival of the younger age groups and general prolongation of life has given rise to numerous new problems of a socio-economic nature, which we are only now beginning to appreciate. This phenomenon is still hardly recognized by our social agencies but will have to be taken into careful consideration in any future planning of social organization.

The very rapid progress in the improvement of human health and in human survival is due primarily to the progress of chemotherapy or the use of chemical substances for the control of diseases in general and of infectious diseases in particular. The greatest advances made in this field during the last few years are due largely to the discovery of the potentialities and utilization first of the sulfa drugs and then of the antibiotics. The first are synthetic compounds and the second are chemical substances of microbial origin. They both have the capacity to inhibit the growth of and even to destroy various microorganisms.

It is, therefore, of great importance at the present time to analyze the birth and development of this new field of science of chemotherapy, which

* Director, Institute of Microbiology, Rutgers University, The State University of New Jersey, New Brunswick. N. J.

has so much to offer to the human race for the continued improvement of its health and survival in the battle against microbial enemies.

There is another aspect to the subject of antibiotics little dreamt of before, that is their importance in agriculture. Only five phases need be considered here: 1. The treatment of animal diseases. 2. The role of antibiotics in animal nutrition, especially non-ruminant animals. 3. Importance of antibiotics as selective sterilizing agents, as in the preservation of bull semen or virus preparations. 4. Potential role in the prevention of spoilage of plant and animal products. 5. Use in the treatment of plant diseases.

Louis Pasteur established beyond doubt that infectious diseases of men and animals are caused largely by microbes. Although he himself did not isolate many of these microbes, he established the significance of infection, and the principles of immunization and vaccine therapy. These ideas dominated our knowledge of the nature and treatment of infectious diseases before the advent of chemotherapy.

Robert Koch is the other great pioneer in the discovery of causation of disease and methods of treatment. His work on the life cycles of bacteria, and his methods for their isolation, cultivation, and staining served further to advance the science of microbiology. It also led him to the discovery, in 1882, of the tubercle bacillus, thus establishing the infectious nature of tuberculosis. Tuberculin, which Koch thought would serve as the therapeutic agent for combating this infectious disease did not justify his expectations. Tuberculin proved to be the first failure among the many "cures" for the treatment of tuberculosis during the next six decades.

Following these investigations, numerous microorganisms responsible for various infectious diseases that afflict man and his domesticated plants and animals were isolated. The mode of transmission of such diseases was established, and means of prophylaxis and therapy discovered.

Paul Ehrlich is largely responsible for establishing the great potentialities of certain dyes and arsenicals in combating certain infectious diseases, such as syphilis. Largely through his work synthetic chemistry opened a way for the final control of numerous human diseases. Ehrlich is spoken of, therefore, as the "father of chemotherapy."

A quarter of a century following Ehrlich's work, the sulfa drugs were discovered. These compounds introduced a new era in chemotherapy. Not only protozoan and spirochaetal diseases were now successfully treated with arsenicals, but bacterial infections as well. In rapid succession, one drug followed another. Each proved to have certain advantages over the previous ones. New compounds were soon added, like the sulfones, which were at first believed to be able to do for tuberculosis what the sulfas did for most of the bacterial infections.

There still remained, however, many diseases which did not respond readily to the sulfa drugs. This was true of diseases caused both by gram-positive and gram-negative bacteria, of various forms of tuberculosis, virus diseases, and certain others. Furthermore, these compounds were found to produce frequent toxic reactions and gave rise, under certain conditions, to drug-resistant strains of bacteria.

Even before these limitations were recognized, a dramatic advance was made in chemotherapy through the discovery of antibiotics. Several major groups of microorganisms, comprising bacteria, fungi, and acti-

nomycetes, were found capable of producing certain substances which had the capacity of inhibiting the growth of and even of destroying disease-producing organisms, not only in the test tube but also in the human and animal body. The recognition of the importance of antibiotics in chemotherapy resulted in a complete change in clinical practice. Diseases never before believed to be susceptible to therapy were now effectively treated. Old drugs were replaced by new ones, which were more effective and less toxic. One of the most important chapters in the history of science and medicine was written before our eyes.

The discovery of antibiotics served to encourage further chemical synthesis. New compounds, some of which proved to be highly effective, were added. This is true particularly of the discovery of the effectiveness of para-amino-salicylic acid (PAS) and isonicotinic acid hydrazide (INH) in the treatment of various forms of tuberculosis. Synthesis was also brought about of one of the antibiotics, chloramphenicol, which proved to be as effective as the microbial product.

The continued search for new antibiotics and the chemical synthesis of new compounds are now proceeding hand in hand toward the ever-expanding battle against infectious diseases of man, animals, and plants.

PRODUCTION OF ANTIBIOTICS

Our modern knowledge of the production and utilization of antibiotics dates back only 15 years. The isolation of tyrothricin from a spore-forming soil bacterium in 1939 was soon followed by the reisolation of penicillin from certain fungi in 1941, and by the isolation from cultures of actinomycetes of actinomycin in 1940, streptothricin in 1942 and streptomycin in 1943. These investigations pointed to the great potentialities of microorganisms as producers of antiinfective agents that could be utilized in human and animal therapy. Large numbers of chemical compounds have been obtained and tested for their antimicrobial properties. The actinomycetes alone have contributed more than 125 active compounds or preparations. The cultures were isolated mostly from soils, water basins, composts, peat bogs, and other natural substrates. They were examined for their ability to inhibit the growth of pathogenic and saprophytic bacteria, of fungi, viruses, protozoa, insects, as well as neoplastic cells. Penicillin, streptomycin, bacitracin, chloramphenicol, polymyxin, chlorotetracycline, neomycin, oxytetracycline, fumagillin, erythromycin, and carbomycin have now taken an important place in the treatment of numerous infectious diseases caused largely by bacteria, spirochetes, rickettsiae, some of the protozoa, and some of the larger viruses. Several other compounds offer promising therapeutic agents in the treatment of a variety of diseases.

The formation of antibiotics is limited to certain species and frequently to certain strains of organisms. Penicillin is produced by a great variety of fungi belonging largely to the genera *Penicillium* and *Aspergillus*. Streptomycin is produced by certain species of *Streptomyces*, notably strains of *Streptomyces griseus*. Both of these antibiotics may be produced in various chemical modifications, as in the case of the various modifications of penicillin or the formation of mixtures of streptomycin and mannosidostreptomycin, or of hydroxystreptomycin produced by *S. griseocarneus*.

Certain organisms produce more than one antibiotic. *Streptomyces griseus*, for example, produces not only streptomycin, active against bacteria and actinomycetes, but also actidione, active against fungi, and streptocin, active against certain trichomonads. Other strains of this organism produce candicidin, an antifungal antibiotic. *S. fradiae* produces not only the antibacterial neomycin but also the antifungal fradicin.

By proper strain selection, by changing the composition of the medium, and by improving environmental conditions, it is possible to increase greatly the yield of each antibiotic, and even to induce certain chemical variations in its molecular structure. Out of several hundred antibiotics isolated during the past 15 years, about a dozen have found practical application as chemotherapeutic agents.

In searching for new antibiotics, certain fundamental principles must be considered:

1. They must be selective in their action against bacteria and other microorganisms, and not act as general antiseptics or disinfectants.

2. They should be effective against those microorganisms that cause diseases which are not now subject to therapy.

3. They should exert their activity in the presence of body fluids.

4. They should not be inhibited by substances present in the blood, and not be destroyed by tissue enzymes.

5. They should not be too toxic, i.e., they should be well tolerated when injected parenterally, taken orally, or applied topically to animals, in amounts required to combat infections, and should not damage the leucocytes in the blood or be injurious to body tissues.

6. They should be excreted readily, but not too rapidly, from the animal body, and should not accumulate to produce undesirable after-effects.

7. They should not favor too rapid development of resistance among sensitive organisms.

There are several bases of classifying antibiotics: (1) Their chemical composition; (2) their antimicrobial spectra; (3) their toxicity to animals; (4) their chemotherapeutic potentialities.

Chemically, antibiotics range from fairly simple compounds, containing carbon, hydrogen, and oxygen, to highly complex substances containing also nitrogen, or nitrogen and sulfur, or nitrogen and chlorine. Some antibiotics are polypeptides, with or without chromophore groups; others are proteins, or benzene ring compounds. Some of the antibiotics represent single chemical entities, whereas others are made up of several closely related compounds. The latter is true, especially, for the penicillins, the streptomycins, and the tetracycline group.

Some antibiotics are active upon a great variety of bacteria, fungi, rickettsiae, and other groups of microorganisms. Others are characterized by narrower spectra, and are active only upon certain groups of organisms, such as some of the gram-positive and gram-negative bacteria. Others have very narrow spectra and are active only upon certain groups of organisms, such as mycobacteria, yeast-like fungi, or certain viruses. Clavacin has a very wide spectrum; penicillin and streptomycin possess somewhat narrower spectra. Chloramphenicol, the tetracyclines, and erythromycin are active against various bacteria as well as against rickettsiae and some

of the larger viruses. Those antibiotics that are active upon bacteria are usually also active upon actinomycetes, but not necessarily upon fungi. Many antibiotics active upon fungi are not active upon bacteria and actinomycetes.

Antibiotics also vary markedly in their toxicity to animals: penicillin is least toxic: actinomycin, streptolin, and xanthimycin are among the most toxic.[1] Clinically, antibiotics vary from important chemotherapeutic agents that are used in the treatment of a great variety of infections, to certain compounds that have so far found no application at all.

Among the various groups of microorganisms, only very few proved to be rich sources of antibiotics, especially those that possess chemotherapeutic potentialities. The fungi have so far yielded only one group of antibiotics that has found practical application in chemotherapy, that is, the penicillins. The bacteria, notably the spore-forming organisms, have contributed several important agents, which have found application in therapy: these include tyrothricin, bacitracin, and polymyxin. The non-spore-forming bacteria have contributed several antibiotics, of which pyocyanase formerly received much consideration: more recently nisin, a product of a *Micrococcus*, showed much promise at first for the treatment of tuberculosis; this has not been confirmed; the colicins have also received much consideration. The most important antibiotics discovered since penicillin have been obtained largely from cultures of actinomycetes, all belonging to the genus *Streptomyces*. These include not only the antibacterial and antifungal agents already listed, but also various antiviral and possibly antitumor agents.

ANTIINFECTIVE PROPERTIES OF ANTIBIOTICS

Antibiotics vary greatly in their selective action upon different microorganisms and in their effect upon the host; the first is usually spoken of as the antibiotic spectrum and the second may be broadly stated to be the relative toxicity of the antibiotic. Both of these characteristics have an important bearing upon the utilization of the antibiotics as chemotherapeutic agents. Some are most effective orally, others parenterally, still others topically. Among the many antibiotics that have so far been isolated, only about a dozen have found practical application.

Antibiotics of Fungi. The true fungi or molds have yielded several hundred active preparations and compounds. Only very few of these, notably the penicillins, have found a place in human and animal therapy. These are still to be regarded as probably the most important groups of antibiotics discovered so far. Penicillin is active chiefly against gram-positive bacteria, certain gram-negative cocci, anaerobic bacteria, and spirochetes. It is the least toxic of all antibiotics known so far. It possesses certain limitations, including lack of activity against many bacteria, a certain degree of sensitization among many individuals, and the gradual development of resistance to it among certain sensitive bacteria. Among the other fungus antibiotics, one need only mention fumagillin.

[1] It is of particular interest to note that this cytotoxic effect of antibiotics may also be selective in nature, and may offer, therefore, great potentialities in the treatment of certain diseases due to malignant cells.

Bacterial Antibiotics. These comprise products of gram-positive aerobic, spore-forming rods, certain micrococci, and certain gram-negative bacteria. Bacitracin, tyrothricin, and polymyxin are the most important. These are polypeptides varying in activity and toxicity. The first two are largely active against gram-positive bacteria and the third against certain gram-negative organisms.

Actinomyces Antibiotics. Streptomycin is the first antibiotic isolated from this group of organisms which has found chemotherapeutic application. It is particularly effective in the treatment of tuberculosis, as well as of numerous infections caused by gram-negative bacteria, such as tularemia, and brucellosis, and by various gram-positive bacteria, especially those that have become resistant to penicillin. Streptomycin has certain limitations. It is apt to cause vestibular disturbance or injure the auditory system. A combination of streptomycin and its chemical derivative dihydrostreptomycin tends to overcome these toxic reactions. Streptomycin favors the development of resistance among sensitive bacteria after prolonged treatment. By combining streptomycin with PAS or with INH, the development of resistance is markedly reduced. Streptomycin forms an ideal combination with penicillin for the treatment of numerous diseases.

Chloramphenicol and the tetracyclines are active upon various gram-positive and gram-negative bacteria, as well as upon rickettsiae and some of the larger viruses. They are usually administered orally and have found extensive application in the treatment of such diseases as typhoid fever, typhus fever, whooping cough, and trachoma.

Among the other antibiotics of actinomycetes that have become established as chemotherapeutic agents, it is sufficient to mention neomycin, erythromycin, carbomycin, and viomycin.

UTILIZATION OF ANTIBIOTICS

Antibiotics have found several important applications:

1. Control of infectious diseases of man.
2. Control of diseases in domestic animals.
3. In the nutrition of poultry, swine, and other non-ruminant and certain ruminant animals.
4. In the preservation of biological materials, such as bull semen, tissue cultures, and virus preparations.
5. In the preservation of plants and plant products.
6. In the treatment of certain plant diseases.

There are other potential agricultural uses, such as seed germination and plant growth.

The treatment of human and animal diseases with antibiotics can be briefly summarized as follows:

1. Diseases Caused by Various Gram-Positive Bacteria and Cocci, Aerobic and Anaerobic Organisms. These bacteria are sensitive to a large number of antibiotics. Organisms that become or are resistant to one antibiotic are sensitive to one or more of the others. Combinations of two antibiotics, such as penicillin and streptomycin, bacitracin and neomycin, have been found to be more effective than a single agent.

2. Diseases Caused by Gram-Negative Bacteria. These are sensitive to streptomycin, chloramphenicol, neomycin, and the tetracyclines. These have found extensive application in the treatment of infections caused by these bacteria. In some cases, some antibiotics are preferable to others. In other cases, as in urinary tract infections, several substances are equally effective, and can thus be used almost indiscriminately. Utilization of the synergistic action of two antibiotics, or of one antibiotic and a synthetic agent, offers considerable promise of exerting a greater effect, especially in a mixed infection, and also tends to overcome the danger of potential development of resistance among the sensitive organisms.

3. Diseases Caused by Acid-Fast Bacteria. The discovery of the effectiveness of streptomycin in the treatment of tuberculosis has provided a great stimulus to the search for antibiotics and synthetic compounds that possess similar properties. The treatment of leprosy has not yet been solved satisfactorily, although some antibiotics have been found to be effective.

4. Spirochaetal Diseases. Several antibiotics have a remarkable effect upon syphilis and other diseases caused by spirochaetes, and have found extensive application in the treatment of these diseases.

5. Rickettsial Diseases. These diseases, including typhus fever, scrub typhus, and spotted fever, are readily subject to therapy by a number of antibiotics, notably chloramphenicol, the tetracyclines, and erythromycin.

6. Fungus Diseases. Various antibiotics are known to possess marked fungistatic and fungicidal properties. None has so far found application in the generalized treatment of infections caused by fungi, except for certain surface applications.

7. Protozoan and Other Diseases Due to Animal Forms. The ability of various antibiotics to suppress the growth of amoebae, trypanosomes, trichomonads, and other protozoa has been definitely established. Some of them have already found practical application in chemotherapy, notably the tetracyclines and fumigallin for amoebic dysentery.

8. Virus Diseases. Some of the larger viruses, notably the psittacosis and lymphogranuloma venereum groups, as well as trachoma, are susceptible to various antibiotics. Their use in influenza, and so-called viral pneumonia, require further elucidation. None are so far known for the smaller viruses, of which the causative agents of the common cold and of poliomyelitis are most important.

9. Neoplasms. Tumor or cancer cells are known to be subject to the action of various microorganisms and their products. The effective agents so far isolated have proved to be too toxic for practical use. Recently, it has been shown that actinomycin is effective against granulomatosa or Hodgkin's disease. These results still require further confirmation and elucidation.

10. Shock and Radiation Diseases. Certain antibiotics may prove to be helpful in combating the injurious action of bacteria present in the intestinal flora and elsewhere in the human body, which may become injurious when the body is subject to shock or to the effect of radiations.

FUTURE OF ANTIBIOTICS

Great progress has been made in our knowledge and utilization of antibiotics since the discovery of tyrothricin in 1939; since penicillin was rediscovered, and the first true antibiotic of actinomycetes (actinomycin) was isolated in 1940. In this brief period hundreds of new chemical substances have been isolated from cultures of various microorganisms, mainly soil borne. About a dozen of these have found extensive application as chemotherapeutic agents. New industries have been created. Many infectious diseases have practically been eradicated.

The development of our knowledge of the nature and utilization of antibiotics has opened many vistas in the control of human and animal diseases, as well as in various fields pertaining to agriculture. The effect of antibiotics in the feeding of non-ruminant animals, in preservation of viruses and other biological materials, and their potential effect in the treatment of plant diseases have taken a definite place in our constant struggle against infectious diseases and the otherwise destructive action of microbes.

Much progress has thus been made, but still more is to be done. There is a great need, for example, for antibiotics active against fungus diseases, against the smaller viruses, and against certain pathogenic protozoa. The search for new antibiotics will, therefore, continue. New approaches will be found and new screening procedures will be developed. Many substances will be discovered which will prove to be better than those we know at present, or which will act upon diseases not susceptible at present to chemotherapy. More profound knowledge of the physiological and biochemical mechanisms of action of antibiotics upon bacteria, viruses, and other pathogenic organisms, may help to clarify the still obscure aspects of their mode of action, and thus possibly lead to the discovery, or even to the synthesis, of new and better chemotherapeutic agents.

Finally, recognition will be taken of the new economic and social problems which are resulting from the greater saving of lives of the younger population, and from the increase in the average age of survival of the human race.

EFFECTS OF ANTIBIOTICS ON HEALTH AND GROWTH OF PLANTS

H. Rex Thomas*

Antibiotics are today well established in the field of human medicine. Also they are extensively used in animal production. Are antibiotics about to become an important factor in plant disease control? To consider this possibility a discussion of recent developments in this field is undertaken. Emphasis will be placed on certain of the more promising greenhouse and field results in which purified or partly purified compounds have been used. For convenience the discussion will be under four main headings based on the use of the antibiotics: seed treatment, protectants, systemics, and growth stimulation. Previous reviews (1, 12, 34, 57) have been most helpful in preparing this paper.

SEED TREATMENT

Ark eliminated the angular leaf spot organism from infected cucumber seed by soaking it in a 100 p.p.m. solution of streptomycin (3). Streptomycin was still present in the seed embryo 2 months after treatment (4). Ark also obtained healthy tomato plants from seed contaminated with bacterial canker organism by soaking it for 20 minutes in a 100 p.p.m. solution before sowing it in the field (4). In the untreated checks 60 percent of the plants were infected. Wyoming workers found streptomycin effective in treating bean seed infected with the halo-blight organism (33, 50). An hour's treatment at 10,000 p.p.m. was needed for complete control in greenhouse tests; however, in the field some infection occurred (51). Streptomycin-treated loose-smut-infected barley seed developed half as many infected plants as the untreated controls (48). Van Schaak found that potato seed pieces artificially inoculated with the ring-rot organism and treated with streptomycin developed healthy plants, whereas the untreated seed pieces rotted in the soil (54). Bonde found that streptomycin sulfate and dihydrostreptomycin were effective in reducing soft rot decay and blackleg disease of potato (9). Other experiments in 1952 indicated that streptomycin was useful against ring rot (8).

Acti-dione (cycloheximide) has shown considerable activity against fungi. Canadian workers obtained good control of covered smut of wheat with Acti-dione by using 0.5 percent dust mixtures with Dixie clay at the rate of $\frac{1}{2}$ ounce per bushel. Acti-dione alone did not improve emergence over that of the untreated check. The organic fungicide captan at the rate of $\frac{1}{2}$ ounce per bushel alone did not control covered smut of wheat satisfactorily. However, when both compounds were used covered smut was controlled and emergence was improved (30).

Research at the University of Notre Dame has shown that soaking or dusting oat grain infected with *Helminthosporium sativum* with Thiolutin at concentrations up to 1 percent increased germination from 88 to 96 percent and decreased disease incidence from 53 percent in the control

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to 3 percent (26). Spergon reduced infection from 95 to 32 percent. Dusting cotton seed with 0.5 to 2 percent Thiolutin resulted in a reduction of *Glomerella gossypii* infection but better control was obtained with Spergon and New Improved Ceresan (26). In England gliotoxin, probably the first antibiotic to be used as a seed treatment, reduced helminthosporium leaf spot on oats, covered smut in barley and bunt in wheat but was inferior to an organic mercury compound (13).

Greenhouse and field tests in Wisconsin have shown that seed treatment with an ethanol solution of a partly purified preparation of helixin B was effective in controlling helminthosporium blight of oats and barley, wheat bunt, oat smut and covered smut of barley (35). Partly purified antimycin A102 was as effective as Ceresan M in controlling the helminthosporium seedling blight of oats (37).

PROTECTANTS

Reports of the use of antibiotics on the aerial parts of the plants as a protective coverage are included in this section. In 1948 Acti-dione was shown by Michigan workers to control powdery mildew of bean when applied as a spray (23). Since then, Acti-dione has been used in experiments to control powdery mildews of rose (55), onion (46) and dewberry (59). Promising results were obtained in the control of cucumber scab (20). Acti-dione was effective in controlling cherry leaf spot in Michigan (38, 39, 49). Hamilton and Szkolnik found that Acti-dione at the rate of 2 p.p.m. controlled leaf spot when sprayed on cherry foliage after an infection period of 96 hours (28). By this time the causal fungus had penetrated to the palisade cells. There was no indication of translocation from one leaf to another. Acti-dione gave as good control of the turf diseases brown patch and dollar spot as commercially used mercury compounds or better control (56). It was effective in controlling melting-out caused by *Helminthosporium* sp. while phenyl mercury did not check this disease at all (56). Fading-out of turf grasses, caused by Curvularia, was checked by Acti-dione (32). In Michigan, a 2 percent Acti-dione dust reduced loss from mint rust (45). Bonde sprayed potato plants with 100 p.p.m. Thiolutin and prevented infection with the late-blight fungus but soil applications were ineffective (10). According to Murneek Thiolutin reduced infection of apple trees by fireblight bacteria (44). Thiolutin gave partial control of frog-eye spot of apples in Delaware (31). Partly purified antimycin A102 was effective against tomato early blight in greenhouse protectant tests (37).

SYSTEMICS

Absorption and translocation of streptomycin were reported in 1947 by Illinois workers (2). The antibiotic was added to a nutrient solution in which soybeans were grown. Four to five p.p.m. of streptomycin was obtained from the extracted sap. This concentration was not enough to protect the plant from infection by *Xanthomonas phaseoli* var. *sojense*.

The translocation of streptomycin in bean plants has been demonstrated by Mitchell and his associates (42, 43). When the antibiotic was applied in a lanolin paste to the stem of young bean plants the development of halo blight on nearby leaves was stopped. By using

a streptomycin-dependent strain of *Escherichia coli* it was shown that the translocated antibiotic was apparently streptomycin as that organism grew on nutrient agar impregnated with the tranlocated material. Streptomycin moved upward through the stem and from the base of leaves to the tip but not in the reverse direction. Translocation of the antibiotic into the pods from the leaves and stem was not observed. Streptomycin could be detected in a leaf near a stem application within 8 hours after treatment. For the next 72 hours the level increased and then decreased until it was relatively low. As much as 67 percent of the total streptomycin applied to bean stems was tranlocated to the primary leaves as free streptomycin during a period of 5 days immediately following treatment. No absorption from soil to which applications were made could be demonstrated in the greenhouse. Dipping halo-blight-infected bean leaves into a 500 p.p.m. solution of streptomycin shortly after the water-soaked lesions developed prevented further development of the disease. Dipping of infected plants 4 to 6 days after the appearance of symptoms failed to control halo blight.

Figure 1.—Field control of halo blight of beans. (Each stake represents an infected plant). Fermate-treated row in foreground with 4 rows to left receiving 4 applications of 1000 ppm streptomycin.

Plant Industry Station workers sprayed snap beans in the field 1 to 4 times with a 1,000 p.p.m. aqueous solution of streptomycin plus 0.3 percent Tween 20 as a spreader (60). The plants were artificially inoculated 3 days after the first spraying. Forty-one percent of the plants

were infected in plots treated once with streptomycin. 10 percent in those sprayed twice, none in those receiving 3 sprays, and a trace in those receiving 4. Ninety-three percent of the plants were infected in the untreated control. In ferbam- and captan-treated plots (4 sprays) 88 and 91 percent of the plants were infected, respectively. Subsequent greenhouse tests indicate that the concentration can probably be lowered to 250 p.p.m. and crude forms of the antibiotic can be used (61).

In 1949 Ark was able to eradicate bacterial speck from tomato plants inoculated with the causal bacteria 24 hours before spraying with streptomycin (4). In Florida, Conover showed in 1952 that streptomycin would control tomato bacterial spot under certain conditions while other available chemicals were not satisfactory if conditions were favorable for spread. In 1953 large-scale plant bed tests were made with a commercial formulation of streptomycin and Terramycin, in concentrations equivalent to 100 to 200 p.p.m. of streptomycin. Five applications were made. Appreciable reduction in infection was obtained by both concentrations. Better control was obtained when the first spray was applied at the time the plants had only the first pair of true leaves than when the third leaf was emerging (19). In preliminary tests Conover obtained control of bacterial spot in pepper beds by using the same concentrations (19).

Probably one of the most promising uses of streptomycin has been in the control of fireblight of pears and apples. In 1951 Murneek sprayed apple trees with a 27 p.p.m. solution of streptomycin (44). With such a low concentration only 60 percent reduction in infection occurred. The following year workers in Delaware obtained a 50 percent reduction in infection with a 30 p.p.m. solution (31). In 1953 Goodman in Missouri obtained 100 percent control of fireblight of apples by using streptomycin and Terramycin in combination at 250-250 and 125-250 p.p.m., respectively, and streptomycin alone at 100 p.p.m. (25). Conrol was complete when the spray schedule was initated at either the balloon stage or at 30 to 50 percent of full bloom. The trees remained free of blight infections throughout the remainder of the growing season. Where the spray schedule was started at early petal fall or at calyx stage some blossom blight developed—about 10 percent of that in the untreated trees. Goodman suggested that this indicates that the antibiotic may have eradicative properties (24). In Ohio, Young and Winter obtained 97 percent control of blossom blight and 100 percent control of twig blight (58). Dunegan, in a preliminary experiment to control fireblight of pears, applied during blossoming 5 sprays of a 100 p.p.m. aqueous solution of streptomycin prepared with a crude form of the antibiotic. The treated trees averaged about 6 infected shoots per tree against about 16 on untreated trees (21). Ark used crude streptomycin as a dust to control pear blight (5). Early season results indicated that it might be as effective as copper-lime dust but considerably more infected shoots had to be removed by June 1 in the streptomycin-treated plots than in the copper-treated ones. However, the streptomycin plot received only 4 applications of dust as compared with 8 for the copper plots. The use of copper as a means of control often causes an undesirable fruit russeting and the use of streptomycin, if proved effective in additional tests, may solve this problem.

Terramycin reduced the severity of halo blight in beans in greenhouse and field experiments (41, 61). Working with fireblight of apples, using

Terramycin at the rate of 120 p.p.m., Young and Winter in Ohio obtained 91 percent control of blossom blight and 99 percent control of twig blight (58). Dunegan, Wilson and Morris injected a small number of peach trees with Terramycin and found that subsequent leaf drop due to *Xanthomonas pruni* infections was much less from the Terramycin-treated trees than from the control trees injected with water (22).

English workers found that griseofulvin was absorbed from nutrient solutions by lettuce seedlings and that these plants were less susceptible to infection by *Botrytis cinerea* than control plants (14). Tomatoes grown in sand culture to which a 500 p.p.m. solution of griseofulvin had been added developed only barely visible, water-soaked, pin-point lesions when inoculated with the early-blight fungus. The period of complete protection given by this treatment was less than 14 days. When a 100 p.p.m. solution was added to the sand some normal-sized lesions developed but 74 percent control was obtained (14). Stubbs (52) also obtained good control of this disease using griseofulvin.

Galls produced by *Agrobacterium tumefaciens* have been killed on many host plants by applying solutions of penicillin or streptomycin as an injection into the gall or on the surface in saturated pads (15, 16, 17, 18, 29). On tomato plants grown in a solution of Aureomycin in mineral nutrient solution Blanchard obtained fewer and smaller galls following needle inoculation with *Agrobacterium tumefaciens* than on similar plants grown in mineral solution alone (7). Concentrations of 5 and 10 p.p.m. of Aureomycin in the nutrient solution gave a slight reduction in the number and size of galls. A dosage of 20 p.p.m. gave practically complete control. Boyle (11) used penicillin effectively in limited tests on a bacterial necrosis of giant cactus.

Few studies on the effects of antibiotics on virus diseases have been made. Work by Gupta and Price (27) and by Bawden and Freeman (6) with growth products produced by *Trichothemium roseum* showed some reduction in infection of southern bean mosaic, tobacco mosaic and tobacco necrosis viruses on some hosts but not on others. They concluded that the antagonistic effects of the substances on the viruses are caused by alteration in host susceptibility. Leben and Fulton tested 9 antibiotics for inhibitory action against three viruses (36). Streptomycin and Terramycin prevented local lesion production on cowpea leaves by tobacco necrosis and tobacco ringspot viruses. The rate of tobacco mosaic virus increase in detached tobacco leaves on a Terramycin solution was less than in control leaves (47).

GROWTH STIMULATION

In 1952 Nickell reported that small quantities of Terramycin added to young corn seedlings stimulated growth (47). After 4 weeks the average height of the corn was greater and the fresh and dry weights greater than those of the untreated controls. Better germination was observed in the treated flats. Sorrell was also benefited by the addition of Terramycin. Experiments with radish with two or more stable forms of penicillin showed that when the antibiotic was mixed with the soil at a rate of 10 units of penicillin per gram of soil, the radishes averaged almost twice to three times as large as those in the untreated soil. Further studies by Nickell with duckweed indicate that certain antibiotics stimu-

late growth although the plants are grown under aseptic conditions. Johnstone at the University of Southern California reported growth increases as great as 75 percent with bean seedlings containing a few parts per million of Terramycin (34). Penicillin and Aureomycin also showed some effect. Studies at Plant Industry Station were made to determine the effects of Terramycin on the germination and early growth of U. S. 13 Hybrid corn, Scarlet Globe radish and Black Valentine bean plants in the greenhouse and in seed germinators. The results failed to show that Terramycin consistently stimulated the early growth of the plants studied (10).

FUTURE

Many antibiotics have been effective in controlling plant diseases in laboratory, greenhouse, and field tests. Acti-dione, particularly active against fungi, is in commercial use, particularly for control of certain turf diseases. This year Agrimycin, a formulation of Terramycin and streptomycin, will be available to research workers for relatively large field tests. Most of the large biological chemical companies have recently established research units to screen their new antibiotics against plant-disease-producing organisms. Plant pathologists are showing increasing interest in evaluating antibiotics for their potential use in controlling diseases on which they are working.

As with any other promising new chemical that is developed for use in plant disease control, an antibiotic must be evaluated for its phytotoxicity, compatibility with other fungicides and insecticides, safety, costs, and ease of use as well as its disease-control possibilities. Toxicity to plants at concentrations necessary for control has been observed with many antibiotics tested so far. For this reason the use of Acti-dione has been limited to certain crops unaffected by it. Streptomycin has been toxic to some crop plants at high concentrations but has been non-toxic on many other plants when used at the lower concentrations that are effective for disease control. When a large potential use exists for a new product, American manufacturers can make use of their noted mass production methods which results in lower prices. This, coupled with the low concentrations needed for control, e.g., 2 p.p.m. of Acti-dione for cherry leafspot control, should give some antibiotics a good chance of competing with currently used organic and inorganic chemicals. The use of Acti-dione costs approximately 40 cents per 1,000 square feet per application to control brown patch, melting-out and fading-out diseases of turf (53). Antibiotics already in production for other uses such as streptomycin, Terramycin, and Aureomycin, which find possible use in plant disease control may be among the first to be used in extensive field trials. The effectiveness of crude forms of the antibiotics for plant disease control is most important because the crude forms are far less expensive than those of high purity. A good control for bacterial diseases of plants has never been available and it is for this purpose that antibiotics may find their first widespread commercial use. The demonstration of eradicant and systemic activity of certain antibiotics may lead to some very significant advances in plant disease control. The use of antibiotics in stimulating plant growth has not been firmly enough established even in laboratory tests to suggest their ultimate use as a practical means of stimulating growth of plants in the field.

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THE VALUE OF ANTIBIOTICS IN ANIMAL NUTRITION

T. J. Cunha and H. D. Wallace*

Antibiotics grew rapidly and became of age in a hurry. It was only in 1949 that it was first reported that products derived from aureomycin fermentation promoted growth of chicks and pigs. The first published scientific paper showing the value of crystalline aureomycin in swine feeding appeared in April, 1950. In the short period since then, a great deal of information on antibiotics has been obtained. More important is the fact that antibiotics are now a part of most, if not all, feeds for young calves, poultry, and swine being sold on the market. This means that the adoption and usage of antibiotics in livestock and poultry feeds was very rapid, indicating their importance and value.

ANTIBIOTICS FOR SWINE

Dr. R. Braude of the University of Reading in England was recently in this country for a year on a Smith-Mundt Fullbright Fellowship. During that time, he spent three months working in our Department. During his stay, Dr. Braude and Dr. H. D. Wallace, who is in charge of the swine work in our Department, and the author reviewed the many experiments conducted throughout the world dealing with the use of antibiotics in swine rations. The results of that survey appeared in a review paper in the *Journal of Antibiotics and Chemotherapy* (Vol. III (3): 271, March, 1953). Certain of those data are presented here and involve the work presented in 111 scientific publications.

The data in Table 1 show that aureomycin and terramycin are more effective than penicillin, bacitracin and streptomycin for swine. The evidence is particularly strong for aureomycin because of the large number of comparisons which have been made. The Florida data showed that aureomycin is very beneficial in increasing the feeding value of the corn-peanut meal ration used. It is recognized that this corn-peanut meal ration is nutritionally inadequate. Thus, the Florida studies are a good example to show that antibiotics give their greatest response with poor quality rations. However, antibiotics are also beneficial when added to as high a quality ration as can be compounded. The data presented from the Hormel Institute and the Nebraska Station were obtained with pigs known to be suffering from digestive disorders. Those results show that the effect of antibiotics is much more pronounced when fed under conditions of digestive disorders, such as would occur under unsanitary conditions.

Following is a brief summary of the information available on antibiotics in swine nutrition and feeding:

1. Antibiotics increase the rate of growth as shown in Table 1. This results in the animal getting to market sooner which saves on labor, etc.

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TABLE 1.—Percentage Improvement in Growth Resulting from Antibiotics Supplementation.

Antibiotics	Florida*	Hormel Institute and Nebraska**	Others†	All Trials‡
Aureomycin	79.3(36)	61.5(34)	15.5(117)	35.9(187)
Terramycin	90.0(1)	51.5(2)	17.6(20)	23.7(23)
Penicillin	—3.0(4)	42.5(2)	10.4(47)	10.6(53)
Bacitracin	—0.5(2)	—	10.9(10)	9.0(12)
Streptomycin	28.0(1)	57.2(6)	9.0(43)	15.2(50)

* Results from Florida were obtained with a corn-peanut meal ration which for some reason gives a big response to certain antibiotics.

** Results from Hormel and some from Nebraska. In their reports, they clearly stated that the control animals used suffered severe digestive disorders.

† This includes all comparisons from the various Experiment Stations except those found in the columns headed "Florida" and "Hormel Institute".

‡ Includes all comparisons available from the various Experiment Stations.

2. They increase efficiency of feed utilization about 2 to 5 percent. While this may appear small, it adds up to a considerable saving to the swine industry. Under conditions of stress, such as unsanitary conditions and poorer quality rations, the improvement in efficiency of feed utilization is much greater. Since conditions of stress are abundant under average farm operations, it must be kept in mind that antibiotic response may be greater there than under Experiment Station conditions. This must be kept in mind in applying the antibiotic data.

3. Antibiotics increase bloom and appearance of the animal. Aureomycin is effective in preventing a skin dermatitis (unidentified type) with certain rations.

4. They help control certain types of non-specified enteritis (scours). This is of considerable importance since enteritis causes considerable loss to the farmer. Some investigators are convinced that in swine nutrition the degree of effectiveness of antibiotic feeding is largely determined by the disease level. The disease level is defined as the degree of feed lot infection with bacterial and/or virus diseases which cause scouring or diarrhea in pigs. Thus, the theory is that the higher the disease level, the more response the animal will receive from antibiotic supplementation.

5. Antibiotics reduce the number of runts and thus makes pigs within litters grow more uniform in size. Runts respond to antibiotic feeding more strikingly than normal pigs. In twelve comparisons an average growth stimulation of 82.2 percent was obtained. Runts or "poor doers" in a herd of pigs are undesirable. Considerable feed is lost or wasted with runt pigs. Moreover, they are more susceptible to disease infection and may spread trouble to the rest of the herd. Thus, the beneficial effect of antibiotics with runt pigs is very important to the swine producer.

6. It has been found that antibiotics exert a "protein sparing" effect. Protein is a costly item and a saving, no matter how small, would have major economic significance. It is not yet clear how much of the protein

sparing effect is due to antibiotic and how much to a more adequate ration fortified with B_{12}, riboflavin, niacin, and pantothenic acid. Evidently, protein requirements have been high in the past because protein supplements were supplying factors other than amino acids. Previous to proper fortification of rations with antibiotics and the four B-vitamins previously mentioned, rations for weanling pigs contained 20-22 percent protein. Recent studies indicate that weanling pigs can now do as well on a ration containing only 14 percent protein. This is a tremendous saving in protein and shows the value of proper supplementation with antibiotics, B_{12}, riboflavin, niacin, and pantothenic acid.

7. The greatest beneficial effect from antibiotics is observed during the early growth period. However, there is ample evidence to indicate that they stimulate growth of hogs during the latter stages of fattening as well. When antibiotics are fed to a weight of 100-125 pounds and then dropped from the diet, the pigs slow down in rate of gain. Thus, for maximum growth it is necessary to feed antibiotics from weaning to market weight.

8. Creep-feeding antibiotics to pigs during the suckling period will increase the weaning weight of pigs five to ten pounds at eight weeks of age. This extra weight enables these pigs to do better after weaning.

9. There are no data to indicate that combinations of antibiotics are more useful than the most effective antibiotic fed alone at the necessary level. This question still needs further exploration however.

10. A level of 5 mg. of antibiotic per pound of total ration (10 grams per ton of feed) is probably quite near the lowest desirable level of antibiotic feeding. This level may vary somewhat depending on the ration used and also on environmental conditions (such as disease level). In some cases, the level fed may need to be higher. However, a 5 mg. level would seem to be adequate in a majority of the cases. There is not sufficient evidence to justify a definite level for each of the effective antibiotics.

11. Several antibiotics such as neomycin, subtilin, rimocidin, polymyxin, and chloromycetin have been tested with generally negative results.

12. Nineteen comparisons conducted on pasture produced an average improvement in growth of 13.7 percent and a corresponding saving of 3.8 percent in feed as a result of antibiotic supplementation. Thus, it appears that antibiotics are effective on pasture as well as in dry lot.

13. Several studies have been specifically designed to determine the role of vitamin B_{12} as it relates to the antibiotic effect. In these tests the average growth response was 15.6 percent for rations containing B_{12} and 11.0 percent when B_{12} was not added. From this evidence, it is apparent that the antibiotic stimulated growth regardless of B_{12} supplementation. However, the best results were obtained when both were added. Additional experiments are needed to clarify the relationship of antibiotic response to other B-complex vitamins.

14. The antibiotic effect is materially influenced by the type of ration fed. Other factors being equal, pigs fed a ration with better over-all nutrient balance will respond less to antibiotic supplementation than those on a poorer ration. Even on good rations there is variation in antibiotic response depending on the feeds used in the ration. Thus, the

quality of the ration as well as the kind of feeds used will affect antibiotic response.

15. Evidence on the value of antibiotics for sows during gestation and lactation is scanty. A few reports are now coming out to indicate that in some experiments, the antibiotic is of value. It is very possible that the beneficial effect is apparent when a stress factor such as quality of ration, disease level (sanitary conditions), etc., is brought into play. Thus, more work is needed to clarify this problem.

16. At the present time, only preliminary information is available on the effect of antibiotics on the swine carcass. These results are not in complete agreement. Studies presently underway should add considerably to the knowledge in this field. When aureomycin is fed at recommended levels of 10 to 20 grams per ton of feed, it cannot be detected in the blood, liver or muscle.

17. The implantation of baby pigs with antibiotic pellets has received considerable attention. First reports were favorable. Extensive testing, however, has resulted in a more conservative attitude and the future of baby pig implants is not certain.

18. The inclusion of antibiotics has been largely responsible for the whatever success "synthetic milk" rations have had. Considerable work needs to be done in this field. Only swine producers with "know how" are likely to be successful with these products. Recent developments indicate that considerable changes have occurred concerning recommendations made a year or so ago on synthetic milk for very young pigs. Taking pigs away from the sow shortly after birth and raising them on substitute sow's milk is a challenging problem which is by no means solved and which still needs a great deal of experimentation.

19. Surfactants have been studied and the results obtained have been variable and inconclusive. Antibiotics are generally more effective than the surface active compounds thus far studied. At the moment, surfactants are an important topic for research, but certainly are not ready for commercial application in swine rations. The future of these compounds as constituents of swine feeds does not appear too promising.

20. Several arsenicals such as 3-nitro-4-hydroxyphenyl arsonic acid, arsanilic acid, phenyl arsonic acid and other related compounds have been reported to have growth promoting properties. Workers at the Hormel Institute and at the University of Minnesota have reported increased gains and an improvement in feed efficiency. Certain of these compounds also proved effective in the control of bloody dysentery. Aureomycin and penicillin were similarly effective. In general, the antibiotics appear to be more dependably effective as growth stimulants for the pig. The main objection to the use of arsenicals is that they are toxic substances with a fairly narrow range between toxic levels and those needed for optimum growth. Thus, the level of feeding must be carefully controlled.

21. As yet, there is no definite evidence which explains the manner in which antibiotics function. Recent studies showed a lack of growth response of antibiotics when fed to germ-free chicks and turkey poults. Work in England, Beltsville and at the Texas Station showed that the growth stimulating effect of antibiotics could not be duplicated by keep-

ing chicks in isolation in new quarters where chicks had not been kept previously. All of that work would imply, as has been thought by most investigators, that antibiotics act upon some system connected directly or indirectly to the microbial flora of the host animal. However, exactly what takes place there is still not known. Some of the possibilities are as follows: (1) Increase of microorganism which produce growth stimulating factor(s); (2) decrease of microorganisms which use up growth factors in the intestinal tract; (3) decrease of microorganisms which produce toxic reactions and thus cause slow growth; and (4) decrease of microorganisms which interfere with absorption of food through intestinal wall.

ANTIBIOTICS FOR OTHER ANIMALS

Dairy Animals

A great deal of work has been conducted on feeding aureomycin to young dairy calves. Aureomycin supplementation increases the rate of growth, decreases the incidence and severity of scours, improves general appearance, increases appetitie, feed consumption and feed efficiency. As far as has been determined, antibiotic supplementation does not have any detrimental effect on the rumen or fecal flora of the calf. Aureomycin supplementation has been shown to be beneficial with calves fed whole milk as well as milk substitutes. Experiments have shown aureomycin supplementation to benefit dairy calves up to 200 days of age. Very little information is available on older animals. Studies at Louisiana and Cornell show no harmful effects from feeding aureomycin to lactating cows. Aureomycin supplementation of the ration did not affect milk production, alter feed consumption, produce digestive disturbances, appear in the milk, effect bacterial flora of the milk, or interfere with the production of a normal curd following incubation. However, there is no reason to include aureomycin in dairy cow feeds based on present information.

Poultry

Antibiotics have been consistent in the promotion of growth of young chickens and turkeys. The growth stimulating effect is the greatest during the early growth period. The antibiotics commonly used are aureomycin, penicillin, bacitracin and terramycin. Antibiotics are now used in most, if not all, broiler mashes and turkey starter mashes. Antibiotic response is greatest with turkeys and pheasants, less in chickens and goslings and least in ducks.

Sheep and Beef Cattle

Early reports with these two classes of livestock indicated that feeding them antibiotics would be harmful. However, it was later found that if lower levels of the antibiotics were used that no harmful effects were obtained. Thus, future studies with sheep and beef cattle will need to take into account that the level of antibiotic fed will be very important. Recent work at the Kansas Station in one experiment showed that aureomycin supplementation reduced the incidence of enterotoxemia in fattening lambs. This important point needs followup study. A few reports are now out showing that aureomycin supplementation increases rate of

growth of fattening lambs. Likewise a few reports have shown that aureomycin supplementation increases rate of growth and efficiency of feed utilization of fattening steers fed a high roughage ration. The preliminary data available indicate that the ratio of concentrates to roughages may be very important in determining whether or not an antibiotic will stimulate growth with beef cattle and sheep. The field of antibiotics and its possible role in beef cattle and sheep is still virtually unexplored. Considerable future research studies are warranted with these two important classes of livestock.

SUMMARY

The information obtained to date shows the value of supplementing swine, chicken, turkey and dairy calf rations with antibiotics. There is very little information available on the role of antibiotics in rations for beef cattle, sheep and other animals. More information is also needed on the effect of antibiotics with all classes of animals during reproduction and for lactation. Future work will undoubtedly throw light on their mode of action and their more exact role in the nutrition and feeding of livestock and poultry.

SYMPOSIUM: BREEDING CROP PLANTS FOR BETTER ADAPTABILITY TO FLORIDA CONDITIONS

FORAGE AND COVER PLANT INTRODUCTION BY THE FLORIDA AGRICULTURAL EXPERIMENT STATION

D. E. McCloud*

Forage and cover plant introductions have played a significant role in the development of Florida's agriculture. Through foreign plant immigrants tremendous changes have taken place in the landscape of this state. Even with the varied flora of southeastern United States, the Indians cultivated only a very few crops. All of our improved forage and cover crops, with the possible exception of St. Augustinegrass, were introduced from foreign countries.

Many forage and cover plants which we use today came into this country at a very early date. Columbus brought alfalfa on his 1493 voyage, and burclover likewise came very early. Pearlmillet was brought from Africa, for food, with the slaves. It was grown by them in this country in the early 1600's. Cowpeas are mentioned by the earliest writers on American agricultural products, and the English botanist Sloane described the Blackeye variety in 1707. Crabgrass and nutgrass were grown in the early southern colonies in the early 1700's. Sugarcane also came into Louisiana at this time.

Washington, Jefferson, and Franklin all saw the possibilities of plant introduction, and Franklin introduced the soybean which was to wait over 100 years for American adoption.

The early history of tropical plant introduction is largely the story of Dr. Henry Perrine, physician and plant enthusiast, as an agricultural pioneer working for the development of the newly acquired territory of Florida. The present Tropical Plant Introduction Garden of the United States Department of Agriculture is located next to the site of his grant. Perrine imported nearly 200 varieties of tropical plants before his death by a massacreing Seminole war party in 1839.

At about this time the Federal Government appropriated $1,000 to the Patent Office for collecting and distributing seeds. By 1850 more than 80,000 packages of seeds were being distributed annually, and this procedure continued until around 1900.

In the Fall of 1887, following the passage of the Hatch Act, the Florida Agricultural Experiment Station was established at Lake City. The first annual report mentions the testing of several forage legumes: crimson, red, white, and hop clovers, common lespedeza, alfalfa, and a vetch. Several grasses also were tested: bermudagrass, timothy, Kentucky bluegrass, red top, and Texas bluegrass. After disappointing results from the northern plants efforts were directed toward the semi-tropical plants.

Natalgrass had the distinction of being the first successful foreign introduction by the infant Florida Agricultural Experiment Station. Seed

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was obtained from the United States Department of Agriculture in 1892; the Department having gotten it from the vicinity of the Cape of Good Hope in South Africa.

The second plant discovered as a forage plant by the Florida Experiment Station, velvetbean, had been grown in Florida since before 1880; its exact date of introduction is unknown though it is native to tropical India and came to Florida via the West Indies. Prior to the first trial at the Experiment Station in 1894 velvetbeans had been used mostly as arbor plants and were believed to be poisonous. By 1914 velvetbeans were grown on over 5 million acres in the South. Up to 1907 practically all the work done on velvetbeans was done in Florida. The first plant breeding research by the Florida Station was the crossing of the common Florida velvetbean to the newly introduced Lyon bean by R. Y. Winter, and John Belling conducted a thorough study of the progeny. By 1914 over 85 different velvetbean introductions had come into Florida through the United States Department of Agriculture.

Japanese cane, a native of China, was the Florida Experiment Station's third contribution. It came to this country from Brazil in 1880, and was first grown in Lonisiana. It was introduced into Florida in 1889 and recommended as a forage crop by the Experiment Station in 1895.

By 1900 several hundred forage crops had been tested by the Florida Agricultural Experiment Station. A herbarium had been established and contained over 1300 sheets. Cowpeas, oats, peanuts, and rice were planted at Lake City, Florida. Beggarweed and crabgrass were being used for hay, and velvetbeans had become a very important farm crop in Florida. The livestock industry was expanding, and according to the Agriculturists of the day, full-blooded razor-back hogs were superior to purebred Duroc-Jerseys. Experiment Station personnel felt that cassavas (tapioca) were destined to be the feed to permit Florida to become a great steer feeding state. The Station's Agriculturist, C. M. Conner, wrote: "We are trying to get a grass suitable for pasture and at the same time one that does not cost too much to get established."

The appointment, in 1905, of P. H. Rolfs as Director of the Florida Experiment Station marked the beginning of a more intensive forage crops introduction program, and shortly thereafter, in 1907, the Station was moved to Gainesville.

Kudzu, a native of Japan, was brought into the United States from the Orient and exhibited at the Philadelphia Centennial in 1876. In Florida, it was grown as an ornamental vine, until it was planted on the Experiment Station in 1909, and recognized as a plant with forage value.

Several crotalaria were introduced from eastern Africa in 1908. They were sent directly to Florida where they were found to be well adapted to light sandy soils of low fertility. By the 1920's the crotalaria were widely planted in Florida for green manure. In the early 1930's the toxic principle of *Crotalaria spectabilis* was discovered, but *Crotalaria striata (mucronata)* continued to be used as a cover crop.

Rhodesgrass, the agricultural value of which was discovered by Cecil Rhodes about 1895 at Capetown, South Africa, was forwarded to the United States by David Fairchild, as S.P.I. 25,017, on one of his plant exploration trips. In 1909 an ounce of seed was sent to the Florida Experiment Station by C. V. Piper. An exhaustive bulletin "Rhodesgrass" was published in 1917 with Director P. H. Rolfs as its author.

Paragrass, native of central Africa and introduced into Brazil at a very early date, has been grown in Florida for many years. A new variety of paragrass was shown to be notably successful in 1910 and was the Agricultural Experiment Station's eighth contribution to Florida's agriculture.

Common bahiagrass, indigenous to South America, was introduced into the United States from Brazil in 1913 as S.P.I. 35,067. It was first planted at the Florida Experiment Station in that same year and was put into a pasture in 1915. It was shown to be well adapted and spread easily by birds, animals, and wind. Common bahiagrass soon became a major contribution to Florida's agriculture.

Caribgrass, native to equatorial Africa, was obtained from Brazil in 1914 by the United States Department of Agriculture, and by 1918 was grown to a limited extent in Florida. It was destined to become an important pasture grass with the development of the rich Everglades soil.

By 1915 almost 1,700 plant introductions had been tested under the intensive program of P. H. Rolfs. Over 85 different varieties of velvetbeans had been introduced from Southeastern Asia. The first pest of this new plant was beginning to discourage farmers from planting the velvetbean—the first example of the usual delay before insect and disease pests become severe on new introductions. An elaborate study of this insect, the velvetbean caterpillar, revealed its life history and showed that successful control measures would await the discovery of new insecticides since the velvetbean plant was unusually sensitive to arsenic. In 1915 a new dairy barn was under construction to expand livestock facilities. The first agronomist, Dr. J. E. Turlington, from Cornell, accepted appointment to relieve Mr. John Scott, Animal Industrialist, of part of his agronomic work.

Napiergrass and Merkergrass were introduced into cultivation by the Rhodesian Department of Agriculture in 1910. These grasses were introduced into this country by the United States Department of Agriculture and sent to Florida where the initial plantings were made in 1915 and 1918. Considerable research showed these grasses to be very high forage producers, and that they could be made into high quality silage.

The first forage crops specialist, J. B. Thompson, was appointed in 1917, to work in cooperation with the United States Department of Agriculture, Division of Forage Crops. With his appointment the forage crops program was resumed with renewed vigor.

Centipedegrass was discovered in China by the famous plant explorer, Frank N. Meyer, who walked over much of the Orient in pursuit of new plants for the United States. Seeds of centipedegrass were found in his baggage after he disappeared on his last trip up the Yangtze River in 1918. Plants were sent to Florida in 1919 as S.P.I. 46,415 and by 1922 centipedegrass appeared very promising. It was the twelfth contribution of the Florida Agricultural Experiment Station.

Alyceclover, native of tropical Asia, was first sent to the United States by J. B. Thompson from the Philippines in 1908. The first records of this plant in Florida are in 1924, but it was not widely planted until the 1940's when it became a valuable hay crop on nematode-free soils.

In 1922 W. E. Stokes was appointed to replace J. B. Thompson as Forage Crops and Grass Specialist, and P. H. Rolfs had resigned as Director to be replaced by Wilmon Newell. The early twenties saw the

establishment of the Tobacco Station at Quincy, the Citrus Station at Lake Alfred, and the Everglades Station at Belle Glade.

In 1927 C. R. Enlow came to the Florida Agricultural Experiment Station in charge of Plant Introductions. He worked in cooperation with the United States Department of Agriculture, Division of Forage Crops, to intensify the search for plant immigrants for Florida's agriculture.

The use of copper and manganese on grasses in the Everglades, an important Station research contribution, was allowing forage development in that region.

The Annual Report of 1929 first lists research by project titles, and Hatch Project No. 107, Crop Adaptation, was written to cover plant introduction research which had begun with the Florida Agricultural Experiment Station sixty years before.

While cowpeas, native to central Africa, have a long agricultural history, an introduction of a new cowpea variety was tested by the Florida Agricultural Experiment Station and found superior to existing varieties. This new cowpea, which first came to California in 1923 and was sent to Florida by the United States Department of Agriculture in 1928, was later named Suwannee.

In 1929 George E. Ritchey replaced C. R. Enlow, in charge of plant introductions, to begin a long and productive career in this work. Yellow lupines were introduced into Florida in that same year, and blue lupines came a year later. These early introductions came from Russia and Poland, but did not seem to be well adapted to Florida. New lupine introductions in 1937 and 1938 from Germany produced especially well in north Florida, as did sweet strains of blue lupine introduced in 1943, and their commercial possibilities were fostered by J. D. Warner of the North Florida Branch Station. Lupines became an outstanding contribution to the agriculture of Florida as well as the entire southeastern United States.

Pangolagrass, although misspelled, was named for its native home, the Pongola River Valley of South Africa. It was first introduced into this country in 1931, and again in 1934 both of these introductions failed. The third introduction of ten plants, P.I. 111,110, came into the United States in 1935, and plants were sent to Florida in 1936. The year 1936 marks one of the great epochs in Florida agriculture, for pangolagrass, the eighteenth contribution of the Experiment Station, soon was to become the backbone of the State's cattle industry.

Hairy indigo, indigenous to tropical Africa, was first introduced into the United States in 1908 and again in 1914 and 1916. It remained in obscurity until 1931 when a small plant was found growing on the grounds of the Florida Agricultural Experiment Station. After being tested it was released, and hairy indigo found an important place in Florida's agriculture both as a forage plant and as a cover crop in citrus groves. An early maturing strain, P.I. 144,994, was introduced from Australia in 1942, and is now widely grown in northern Florida and adjacent states.

The early 40's contributed several valuable forage and cover crop plants. Paraguay bahiagrass, from South America, was tested and found a place in the agriculture of Florida. Pensacola bahiagrass was found growing near the docks at the Florida city bearing its name by County Agent E. H. Finlayson. This grass was tested and evaluated by the Experiment Station and became one of the major contributions to Florida's

TABLE 1.—Foreign Plant Contributions of the Florida Agriculture Experiment Station.

	Common Name	Botanical Name	Native Home	Date Introduced into Florida
1.	Natalgrass	*Rhynchelytrum roseum* (Nees) Stapf and Hubb	South Africa	1892
2.	Velvetbean	*Stizolobium deeringianum* Bort.	India	1894*
3.	Japanese cane	*Saccharum sinense* Roxb.	China	1895*
4.	Kudzu	*Pueraria thunbergiana* (Sieb. and Zucc.) Benth.	Japan	1909*
5.	Crotalaria, striata	*Crotalaria mucronata* Desb.	Africa	1909
6.	Crotalaria, showy	*Crotalaria spectabilis* Roth	Africa	1909
7.	Rhodesgrass	*Chloris gayana* Kunth.	South Africa	1909
8.	Paragrass	*Panicum purpurascens* Raddi.	Africa	1910*
9.	Common bahiagrass	*Paspalum notatum* Flugge.	Brazil	1913
10.	Caribgrass	*Eriochloa polystachya* H B.K.	Africa	1914*
11.	Napiergrass	*Pennisetum purpureum* Schumach.	Rhodesia	1915
12.	Centipedegrass	*Eremochloa ophiuroides* (Munro) Hack.	China	1919
13.	Alyceclover	*Alysicarpus vaginalis* (L.) D.C.	Asia	1924*
14.	Suwannee cowpea	*Vigna sinensis* (L.) Endl.	Africa	1928
15.	Yellow lupine	*Lupinus luteus* L.	Germany	1929
16.	Blue lupine	*Lupinus angustifolius* L.	Poland	1930
17.	Sweet blue lupine	*Lupinus angustifolius* L.	Germany	1943
18.	Pangolagrass	*Digitaria decumbens* Stent.	South Africa	1936
19.	Hairy indigo	*Indigofera hirsuta* L.	Tropical Asia	1931*
20.	Early Hairy indigo	*Indigofera hirsuta* L.	Tropical Asia	1942
21.	Paraguay bahiagrass	*Paspalum notatum* Flugge.	Paraguay	1938
22.	Pensacola bahiagrass	*Paspalum notatum* Flugge.	South America	1936*
23.	Argentine bahiagrass	*Paspalum notatum* Flugge.	Argentina	1944
24.	Blanket indigo	*Indigofera pilosa* Poir.	Asia	1947

* Date of discovery of forage value.

Figure 1.—Native Homes of the Forage Plants Contributed by the Florida Agricultural Experiment Station.

pasture development. Argentine bahiagrass, introduced as P.I. 148,996, was named for its South American home. It came to Florida in 1944 and added to the list of new forage grasses. Argentine bahiagrass was the twenty-third contribution of the Florida Agricultural Experiment Station.

Blanket indigo came into Florida in 1947 and is now in limited commercial production, but it is too early to evaluate its potential to Florida's agriculture.

In 1950 George E. Ritchey, after 21 years of plant introductions work resulting in a half-dozen new crops, was advanced to the Suwannee Valley Experiment Station as Agronomist in Charge, and the forage introductions program continues under D. E. McCloud.

Thus, after sixty-six years of forage plant introductions some twenty-four plants have been released to be used by Florida's farmers, Table 1. It is estimated from Agricultural Marketing Service and Production Marketing statistics that pangolagrass is now grown on over one-half million acres in Florida. The bahiagrasses are planted on about 400 thousand acres. Lupines are grown on almost 120 thousand acres on groves and ranches. Velvetbeans and cowpeas are planted to almost forty thousand acres each on Florida farms. Alyceclover is grown on about fifteen thousand acres each year. These crops alone account for over one-million acres of Florida crop land and have wrought great changes in Florida's landscape.

The large scale introductions program in cooperation with the United States Department of Agriculture has brought over 8,000 new plants into Florida. These plants have come from four continents and over a dozen foreign countries, Figure 1. Yet, even today it is estimated that we have only one-fourth the plant resources of Europe and not more than one-tenth of those of Asia. Continued introductions from the wealth of plant material available throughout the world must then lead to innumerable new unheard-of plants from the far corners of the world to meet the challenge of our increasing population.

A COORDINATED SMALL GRAIN BREEDING PROGRAM FOR FLORIDA AND SOUTHEASTERN UNITED STATES

W. H. Chapman*

The primary purpose of a plant breeding program is to produce varieties or hybrids that are efficient in their use of plant nutrients, that give the greatest return of high quality products per acre, and that are adapted to the needs of the grower and consumer. Such agronomically adapted varieties are dependent on resistance to disease, lodging, and shattering; and on winter hardiness, yield, and quality. In Florida, disease resistance contributes more toward productivity than any of the other characteristics.

Numerous workers have pointed out the effect of changes in varieties on variations in the importance of certain plant pathogens. The plant breeder has greatly influenced the rapid build-up and spread of plant pathogens by the simultaneous release over wide areas of oat varieties which are susceptible to specific diseases. The release of large numbers of Victoria derivatives followed by numerous Bond-related varieties are examples of this pattern in the United States. In Florida, these changes in varieties resulted in a severe outbreak of Victoria blight in 1946 and 1947, followed by heavy infections of crown rust, races 45, 57, and similar races, which together caused almost complete failure of the oat crop from 1946 to 1950. Such conditions cause oat breeding problems to be regional in scope and similar situations exist in respect to other small grains. This suggests a coordinated breeding and testing program for Florida and the southeastern states.

High annual rainfall, high humidity, and a relatively warm growing season furnish ideal conditions for maximum development of small grain diseases in Florida. Several times new and more virulent forms of disease organisms have increased rapidly to destructive proportions. Although such conditions are not conducive to maximum yields, they are excellent for breeding and testing for disease resistance. In 1947 and 1948 the small grain breeding nurseries were virtually destroyed by numerous diseases. Often the prevalence and severity of crown rust of oats, leaf rust of wheat, and stem rust of both in Florida might be indicative of future epidemics in sections of the country farther north. The situation in Florida, together with specific disease situations in other sections of the southeast, probably influenced the allocation of Research Marketing Act funds for 1949-1950, to pathological research. At the 1949 meeting of the Technical Committee of the Regional Research Project on breeding, culture, fertilization, and storage of small grains in the South, it was proposed "that research pathologists be located in three different sections of the South—each to give special attention to one or two diseases of major importance in the area where he is located, to survey the importance and make observations on other diseases of small grains

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in the area, and to develop techniques for testing resistance to the diseases, and to cooperate with the agronomists in breeding for disease resistance."[1] The three general locations are as follows: (1) Virginia, North Carolina, and the Piedmont and mountain areas of South Carolina and Georgia; (2) Coastal Plain and lower Piedmont of South Carolina, Georgia, Florida and Alabama; and (3) Blackland area of Western Alabama, Mississippi, Arkansas, Louisiana, and Eastern Texas. Headquarters for the three pathologists are Raleigh, N. C., Gainesville, Florida; and State College, Mississippi.

This step made available new pathological research on diseases of small grains which was needed before efficient and enlarged breeding programs could be developed in the southeast. In Florida crown or leaf rusts, smuts, some leaf-spotting diseases, and stem rust lend themselves to heavy artificial epidemics in field tests. Maximum use is made of breeding nurseries to obtain response to naturally occurring diseases and, when applicable, added amounts and kinds of disease organisms are introduced and encouraged. Agronomic nurseries are not practical for the study of certain diseases and in this case separate disease nurseries are grown. Laboratory tests with diseases not adapted to field testing are conducted to supplement the mass testing of lines in the field. These services are available to anyone conducting breeding programs in Florida or the Southeastern region.

Other phases of the pathologists' program include the following: (1) Comprehensive testing of advanced lines and prospective parental material, (2) basic studies of the culm rot organism, (3) seed treatment studies and their effect on commercial planting, (4) material for artificial inoculation of breeding nurseries, and (5) basic work on the nature and cumulative effects of factors for crown rust resistance.

The final results of this coordination between the plant pathologist and the plant breeder are tested by planting Uniform Florida Small Grain Nurseries at the branch stations and Mobile Units.

This cooperation in Florida is made possible by certain practices that also augment the breeding programs in the other Southeastern States. These states in turn have services which are of tremendous value to the Florida program. At the 1953 meeting of the Technical Committee of the Regional Research Project, the possibility of cooperative testing of early generations of small grain bybrids was discussed. Preliminary aspects of interstate cooperation as well as its potentials will be discussed briefly.

Early maturity under Florida conditions allows hybrid combinations to be made sufficiently early to be harvested in ample time for planting at the Federal Substation at Aberdeen, Idaho. Growing two crops a year materially hastens a breeding program; however, this is not possible in the northern sections of the southeastern region. With the addition of a few varieties to the Florida crossing block, hybrid combinations suitable for the northern stations could be made in ample time for planting in Idaho. The Florida workers do not have enough time to make these crosses, but if breeders in other states would take advantage of a Florida crossing block, they could make sufficient hybrids in a short time.

[1] Report of the Technical Committee of the Regional Research Project; Breeding, culture, fertilization, and Storage of Small Grains in the South.

For the past four years Florida has taken advantage of being able to grow summer crops in Idaho. As an example of the rapid increase of seeds, 127 F_1 plants grown in Idaho during the summer of 1953 produced approximately 80,000 seed. The large second generation was space-planted and subjected to heavy artificial epidemics of crown rust, stem rust, and culm rot. All susceptible plants were discarded, virtually assuring F_3 plantings of highly disease-resistant material.

More northern stations can expect natural infection of crown and stem rust infrequently, however mosaic infested soil and cold winters afford excellent opportunities for testing early generation material. The seed mentioned in the preceding paragraph represent less than half of the hybrid seed obtained in Florida in the spring of 1953. Neither funds nor facilities permitted all of the hybrid seed to be grown in Idaho. If such had been possible, a large number of F_1 seed could have been divided among the southern states and tested under disease and weather conditions specific to their locality. The interchange of this material for growing and testing in the third generation would afford lines resistant to prevalent diseases and conditions in the southeastern states.

By taking advantage of natural conditions as well as facilities available for specific testing, certain states offered services for the interstate cooperative program listed in Table 1. This is only a start and it is anticipated that the plan will be developed further in the next few years.

TABLE 1.—Services Available for the Interstate Cooperative Program Initiated by Techinal Committee of Regional Research Project.

Crop	STATE					
	Florida	Mississippi	Georgia	Virginia	Kentucky	North Carolina
Oats	Crown rust Stem rust Culm rot	Victoria Blight	Crown rust Stem rust	Winter-hardiness	Winter-hardiness	
Wheat		Leaf rust* Races 5,35,122 Septoria		Winter-hardiness	Winter-hardiness	Loose smut Powdery Mildew
Barley		Scald			Winter-hardiness	Loose smut Powdery Mildew

* Greenhouse tests.

Such a testing program can only be successful if material is freely interchanged between stations. The idea is not new. In 1936 Dr. H. H. Love of Cornell University wrote the following: "It seems to me that much valuable material is wasted or lost due to the fact that there is no thorough coordination between the different stations. I urged that this be considered more than 10 years ago in the hope that materials produced at one station might be tested at other stations."[2]

[2] Yearbook of Agriculture: United States Department of Agriculture 1936, p. 260.

Problems other than disease resistance, which are concerned with the improvement of small grains, are also important in more than one region. Many of these can best be solved by a joint cooperative undertaking of all regions and agencies concerned. Several of these will be mentioned.

The advantages of two crops per year have been pointed out. This is possible by growing a winter crop of the spring and intermediate types at a southern station and a summer crop at a northern or western station. By extensively studying the possibilities of vernalization as well as a combination of locations, a workable plan for winter small grains might be found.

Because of erratic weather conditions, winter hardiness data from field nurseries are difficult to obtain. Since there is a close correlation between artificial freezing tests and field conditions, a suitable laboratory could do much to learn more about basic information on hardiness as well as to classify existing varieties and parental material. This cooperative program would help to incorporate considerably more disease resistance into the winter hardy varieties.

Little is known about measuring the forage value of breeding material or about the effect of time and method of pasturing on the yield of forage and grain. A technique for determining forage value of early generation lines would aid considerably in breeding better forage types for the Southeast. As these types are developed it would also be of value to determine the reaction of the different strains under the various environmental conditions.

Much work needs to be done on the relationship of genes for resistance to specific physiologic races of disease organisms. Cataloguing promising breeding material and varieties for reactions to individual races would aid considerably in establishing the ultimate worth of this material.

Basic research is necessary for continuous progress in crop improvement. The knowledge gained from studies on genetics, cytogenetics, physiology, breeding methods, species crosses, etc., would be applicable in all regions. If this material could be made available widely and as quickly as possible, it would avoid duplication and increase the efficiency of the individual operations. Probably the greatest progress in these fields can be made by augmenting the work now under way at certain stations. Other agencies also probably have facilities and funds to permit the expansion of such studies.

Time does not permit the discussion of all the regional problems, but some of the others are as follows: (1) New techniques for producing artificial epidemics of diseases, (2) response of varieties to fertilizer practices, (3) effect of different environments and fertility levels on nutritive value of forage and grains, (4) grain quality studies, (5) laboratory for designing experimental small grain equipment, (6) cooperative planning of hybrids and parental material to be used and, (7) genetic constitution of varieties to be used as parents, and many others.

Many workers feel that the beginning of a coordinated program for the southeastern region will do much to add to the efficiency of the individual projects. It is felt that the potentials of such a cooperative project are almost unlimited. However these potentials cannot be developed unless the individuals adhere to the true meaning of the word cooperate—to regulate and combine in harmonious action and to concur in action, effort, or effect.

THE IMPORTANCE OF DISEASE RESISTANCE IN SMALL GRAIN IMPROVEMENTS*

R. W. Earhart**

The first prerequisite for the successful production of any crop is its adaptability to the area of growth. Normally, adaptation means compatability of the plant with its physical environment, primarily the climate and the soil. However, all environments contain other plants and animals which inhabit, or are capable of inhabiting, the same ecological niche as the crop plant. Among these frequently are predator diseases and pests, which the crop plant must be able to survive if it is to be of agricultural importance. This paper discusses the importance of plant diseases in the growing of small grains in Florida and the role of the plant pathologist in protecting these crops.

I. The Effect of Diseases on Oat Yields in Florida

In Florida, the climate and soils are suitable for small grain culture during the winter months. However, this mild winter climate is also conducive to fungal and bacterial organisms which can reduce small grain production severely.

TABLE 1.—Florida Oat Production, 1940 to 1954*.

Year	Harvested Acres	Total Production	Per Acre Yields
1940	11,000	154,000	14
1941	11,000	170,000	15
1942	9,000	168,000	18
1943	12,000	300,000	25
1944	20,000	400,000	20
1945	45,000	900,000	20
1946	40,000	720,000	18
1947	30,000	600,000	20
1948	21,000	399,000	19
1949	18,000	288,000	16
1950	16,000	288,000	18
1951	20,000	500,000	25
1952	36,000	1,080,000	30
1953	40,000	1,120,000	28

* Production figures from the U. S. Dept. of Agriculture Bureau of Agricultural Economics.

Oat production has reached highs for this State twice during the past decade. These were times when the currently limiting diseases were con-

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trolled temporarily. Production reached 900,000 bushels in 1945, and 1,120,000 in 1953. However, as is shown in Table 1, there have been intervening points of low production when uncontrolled diseases materially reduced total production. Figure 1 presents the average yields per acre of oats in Florida from 1940 to 1954 with a graphic correlation of the varieties in use and the relative importance of the major diseases during this period.

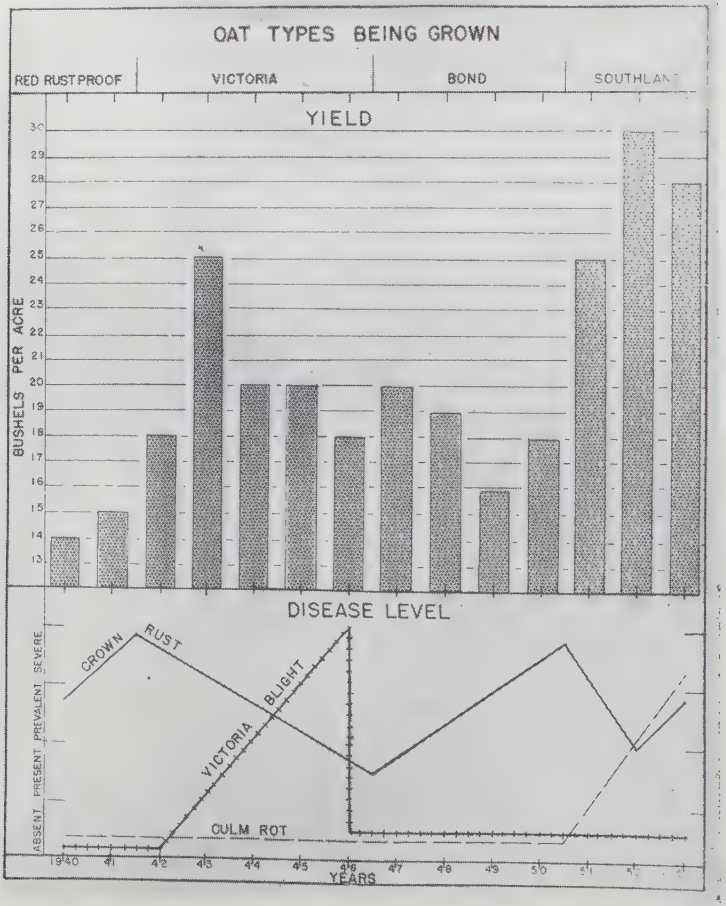

Figure 1.—Graphic Correlations Between the Oats Being Grown in Florida, the Average Yields per Acre, and the Level of Three of the Major Oat Diseases from 1940 to 1954.

As illustrated in Figure 1, the yield of oats rises and falls inversely with the prevalence of the diseases. Both yields and diseases are directly correlated with changes in varieties. Victoria blight, *Helminthosporium victoriae* Meehan & Murphy, rose and fell in prevalence with the increase and decrease in the acres of oat varieties having the Victoria variety in their pedigrees, since this disease is known to be damaging only on such

varieties. This strict varietal specificity is very limited, and the rapid rise and fall in the severity is rather unusual among oat diseases.

Oat crown rust. *Puccinia coronata avenae* Eriks. & Henn., is more typical in its behavior, having a gradual rise and fall as varieties change, but increasing as a particular susceptible type of oat is in use. This phenomenon occurs since different races of this organism are able to attack different varietal types of the crop. When a variety which is susceptible to a particular race of rust is replaced by a resistant variety, this race declines for a while. This is shown in Figure 1. As more Victoria derivatives were grown, crown rust became of lesser importance. However, with the shift to Bond derivatives, there was a rather quick build-up of crown rust race 45 which could attack these oats. The drop in the importance of crown rust between 1950 and 1952 was due to the resistance of Southland to race 45, and the rise of rust in 1953 was correlated with the increase of race 101 which can attack Southland. The drop in yields per acre in 1953 followed the increased importance of crown rust and oat culm rot. *Helminthosporium sativum* Pam., King, & Bakke, to which Southland is particularly susceptible.

II. Importance of Disease Resistance in Florida Varieties

The increase in the harvested acres of oats in 1945-46 and 1951-53 (Table 1) represents the confidence that Florida farmers place in oats as a grain crop when they are able to grow varieties relatively free from diseases. Freedom from disease is not a lucky chance, but is the result of many years of work by agronomists and pathologists, who devote themselves to the task of improving varieties. The high production of 1945-46

TABLE 2.—Florida Small Grain Diseases.

Oat Diseases

Crown rust—*Puccinia coronata avenae* Eriks. & Henn.
Stem rust—*Puccinia graminis avenae* Eriks. & Henn.
Culm rot—*Helminthosporium sativum* Pam., King, & Bakke
Leaf spot—*Helminthosporium avenae* Eidam
Victoria blight—*Helminthosporium victoriae* Meehan & Murphy
Loose smut—*Ustilago avenae* (Pers.) Rostr.

Rye Diseases

Leaf rust—*Puccinia rubigo-vera secalis* Eriks. & Henn.
Stem rust—*Puccinia graminis secalis* Eriks.
Leaf blotch—*Helminthosporium tritici-repentis* Died.

Wheat Diseases

Leaf rust—*Puccinia rubigo-vera tritici* (Eriks.) Carleton
Stem rust—*Puccinia graminis tritici* Eriks. & Henn.
Powdery mildew—*Erysiphe graminis tritici* El. Marchal.
Septoria leaf spot—*Septoria nodorum* Berk.

Barley Diseases

Spot blotch—*Helminthosporium sativum* Pam., King, & Bakke

resulted from the incorporation of the Victoria-type resistance to oat crown rust into the locally adapted varieties Quincy 1, Quincy 2 and Florilee. The 1951-53 rise resulted from the use of Southland, which combined resistance to both crown rust and Victoria blight. The subsequent release of Floriland, Sunland, and Seminole, new additions of disease resistance into Florida oat varieties, has not yet been reflected in the total oat production.

Not all diseases have received as much attention as have crown rust and Victoria blight. Oat improvement projects are slowly accumulating resistance to the prevalent diseases, and those that inflict the greatest damage receive the most attention. This is why we now have crown-rust-resistant-oats available for growing in Florida, but not leaf spot, *Helminthosporium avenae* Eidam, resistant oats. Table 2 lists the small grain diseases of Florida in their current relative importance, which is the approximate order that they are being investigated.

III. Role of the Pathologist in Breeding for Disease Resistance

The pathologist has three realms of activity in any program designed to secure disease resistance in small grain crops. The first is providing fundamental information about the disease and its cause; second, providing disease-resistant parental material for the breeding program; and third, testing resulting progenies to select those possessing the desired resistance.

A. Information about a disease and its cause is essential to any search for resistance. Activities in securing disease resistance in a crop are based upon the answers to the following questions.

1. *What causes the disease?* Is it due to the activities of a parasite, or is this condition a nutritional or physiological unbalance?

2. *What factors influence the severity of the disease?* Is this disease effected by peculiar conditions of climate, crop relationships, soil, nutrition, or cultural practice? In this regard, many crop diseases are controlled effectively by using good cultural practices, including crop rotation, cleaned and treated seed of recommended varieties, adequate fertilizer, controlled grazing, and timely harvesting.

3. If this disease is caused by a parasite, then—
   a. *What factors effect the growth and parasitism by this organism?*
   b. *Will this organism attack other plants, or is it limited to just this crop plant?*
   c. *Where are the vulnerable periods in the growth and development of the particular organism?*

4. *How economically important is this disease?* Does it now, or will it, effect the agricultural economy of the area? The answer to this question will be based upon surveys of present damage.

5. *Can the disease be produced artificially?* When a disease can be developed under controlled conditions, the pathologist is not limited by a chance occurrence of the disease under natural conditions to study the organism or to select for resistance.

6. *Are there any effective control measures?* Frequently resistant varieties can be introduced and grown, or diseases may be kept in check by modified cultural practices to avoid the disease or by the timely application of fungicides to control the parasite.

B. *Providing Disease Resistant Parental Material.*

Three general sources of material are available when seeking disease resistant parental material: (1) new varieties developed by breeders in the United States, (2) foreign introductions, and (3) lines originating from induced mutations. Of these, foreign introductions usually are the most fruitful since they represent more diverse sources of germ plasm likely to have resistance. The new breeding lines frequently carry unsuspected sources of resistance, which may be due to the additive, or transgressive effects from combining two older sources of resistance. Induced mutations are just now becoming important in plant disease resistance. Recently, there has been some new types of resistance secured from mutations induced by irradiations and other mutagenic means from established varieties.

To provide plant breeders with new sources of disease resistance, a large number of varieties and selections are tested by subjecting them to artificial inoculations with specific disease organisms under conditions favorable for disease development. The resistant ones, often only a few, are retested, then recommended to the plant breeders to be included in their improvement programs.

C. *The Use of Eestablished Resistance.*

In any locality there are certain preferred types of crops that most nearly meet the specific agricultural needs of the area. It is the task of the plant breeder to "tailor make" these types of crops that the farmers require. In Florida, all oats must be capable of furnishing winter grazing, preferably as early as December 1, and as late as March 15. This means that disease resistance must be incorporated into agronomically desirable lines. To do this, all progenies of any cross bringing together agronomic desirability and disease resistance will have to be tested in early generations to determine whether or not they possess these characters. This task of the pathologist again contributes to the breeding for disease resistance.

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PEANUT BREEDING AND VARIETY RESPONSE TO ENVIRONMENT

W. A. Carver*

This paper gives a discussion of the peanut breeding work at the Florida Stations. It also gives a discussion of the response of different peanut varieties to environmental conditions.

The first breeding work conducted by the Florida Experiment Station for peanut improvement was pedigreed selection in commercial seed stocks of the Small White Spanish variety. Later, variety hybridization was started, generally crossing small seeded varieties to large seeded ones. From advanced generations of these crosses lines have been found which produce high yields of good quality seed. Three such lines proved their superiority in variety tests conducted over a four-year period. The lines have been named Dixie Runner, Early Runner, and Florispan Runner and released to Florida growers for general planting.

PEANUT BREEDING, METHODS AND RESULTS

The most important objectives in the variety improvement work are high yield of peanuts and good quality of seed. High yield and good quality are first selected by choosing desirable plants. In later years high yielding plant-rows and strains are selected. Highest yields have been made by strains of runner plant type. Other desirable characters selected are: (1) good flavor, (2) high oil content, (3) conventional size and shape of seed that can be processed with currently used machines, and (4) seed with smooth surface to allow easy blanching. During the 1920's and early 1930's pedigreed selection within Small White Spanish varieties was practiced. The selected lines of Spanish showed some superiority over commercial Spanish peanuts, but the gains were not considered satisfactory. In 1928 hybridization was begun between different variety types.

The methods used in crossing peanuts stated briefly follow:

1. Parent seeds are planted in 4-gallon pots in a heated greenhouse on March 1.
2. Crossing begins about April 20 and lasts for one month. If temperature is much below 60° F., flower stalks do not elongate and the flowers do not fully develop.
3. Emasculation of flowers is made from 9 to 11 P.M. A white sewing thread is looped around the flower stalk to mark it as being emasculated.

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4. Pollination is completed the following morning between 7 and 8 o'clock. A small copper wire replaces the white thread when the peg has grown downward to the length of about one inch.
5. The crossed seeds, which are marked by copper wires around the pegs, are harvested in July.

Stokes and Hull (6) have described the technique used in the hand pollination of peanuts.

Pedigreed selection is started in the second generation of hybrid lines. As a rule, a very small percentage of the second generation plants has favorable character of plant or seed. The high seed quality of Small White Spanish peanuts has been very difficult to isolate from hybrid lines. Frequent rains and high humidity during the harvesting season in Florida causes a high degree of concealed damage, or "bitter heart", as it is sometimes called. Wilson (7) studied the relation of seed moisture and concealed damage in peanut varieties by using containers in which the moisture percentage was controlled. He found that seed damage developed faster when moisture was held between 15 and 35 percent, and was slower above and below this range. Hence, humid conditions in the field which prolong the time of seed curing can increase the amount of seed damage. The disease organism most frequently causing seed damage was *Diplodia theobromae*. Many attempts have been made to select a good hay-type peanut. In such types it appears that the yield of nuts must be sacrified for hay yield. Furthermore, a light hay yield usually aids rapid curing of the peanuts, resulting in high quality seeds.

Standard varieties and types that have been used in crosses are Small White Spanish, Improved Spanish, Pearl Spanish, Valencia, Tennessee Red, Tennessee White, Georgia Bunch, Virginia Bunch, Virginia Jumbo Runner, North Carolina Runner, Nambyquarae, and Rasteiro. In recent years, hybrid lines have been intercrossed and backcrossed to standard varieties.

During the period from 1928 through 1952, 81 different cross combinations were made totaling 173 crosses. The variety types that were used in hybrid combinations more often are:

White Spanish x Va. Jumbo Runner, 10 crosses
(White Spanish x Va. Jumbo Runner) x White Spanish, 10 crosses
(White Spanish x Va. Jumbo Runner) x Va. Jumbo Runner, 9 crosses
White Spanish x N. C. Runner, 8 crosses
White Spanish x Ga. Bunch, 7 crosses

Dixie Runner was selected from a cross between Small White Spanish and Dixie Giant. The latter variety is a large seeded Virginia Runner type peanut bred by the U. S. Department of Agriculture. Early Runner and Dixie Runner originated from the same cross. Florispan Runner was selected from a cross between Ga. 207-3 and a hybrid strain from Dixie Giant by Small White Spanish.

In the variety tests over a period of years these new varieties have produced higher yields of peanuts per acre than common runners and have had about one-half the amount of seed damage.

Since 1944 the five more popular parents in making crosses have been (1) Dixie Runner, (2) Virginia Jumbo Runner, (3) Fla. Sta. 249: Pearl Spanish (White Spanish x Va. Jumbo Runner), (4) White Spanish, and (5) Florispan Runner. These have been intercrossed and crossed to a large number of hybrid strains.

Further selection is being made in Florispan Runner, Dixie Runner, and Early Runner. A number of lines and sub-lines of each variety are grown yearly. Plant selections from each variety-line are also made periodically in order to maintain variety purity, and to improve them further if possible. During the years when variety plant-row selections are not grown, a number of strains from each variety are grown and carefully rogued for off-type plant and seed characters.

Breeder seed of the Dixie Runner variety is further increased at the Mobile Unit Station at Marianna and the West Florida Station at Jay. Breeder seed of the other two varieties, Early Runner and Florispan Runner, are grown only at the main station in Gainesville.

On the main station farm from 7 to 10 acres are planted to the peanut breeding nursery each season. This includes a variety-strain test, seed increase plots, and selection plant-rows.

TABLE 1.—Yield Differences Between Florida Runner and G.F.A. Spanish when Grown at Gainesville and at West Florida Stations. Yields Are in Sound and Mature Seed, Expressed in Percentage.

Years Grown	Locations Planted: Gainesville		West Florida Stations		
	G.F.A. Spanish Yields	Florida Runner	G.F.A. Spanish	Florida Runner	
	Yields in Percentage				
1946	38	100	71	100	Quincy
1948	67	100	100	100	Marianna
1950	63	100	85	100	Marianna and Jay
1951	39	100	130	100	Marianna and Jay
Average	52	100	97	100	

The average yields during the four years tested show that Spanish yielded about one-half of Florida Runner at Gainesville, but was nearly as productive as Florida Runner in West Florida.

VARIETAL DIFFERENCES IN RESPONSE TO ENVIRONMENT

A review of literature on varietal differences in response to fertilization is given by York and Colwell (8) in a symposium entitled, "The Peanut". Some of the differences in behavior reported follow:

1. Virginia type peanuts (large seeded varieties) gave large increases in yield of peanuts from applications of gypsum.

2. Small seeded types were less responsive to gypsum, but produced increased yields with additions of N, P, and K. Nitrogen was especially beneficial to Small Spanish.
3. There appeared to be decided differences in the nutritional requirements of varieties within both of the above groups.
4. Va. Bunch performed better on some N. C. Soils than Jumbo Runner, whereas the reverse was true on other soils.

In later experiments further differences in response to fertilization have been found. Harris (5) found that the visual symptoms caused by the lack of copper were more severe in G.F.A. Spanish peanuts than in Dixie Runner and Alabama Runner.

Futral (4) reports that Spanish peanuts require more nitrogen and less phosphate and calcium than do larger seeded types. The potash requirements of all varieties appear to be similar. Runners repond well to phosphate and potash whereas Spanish Peanuts do not repsond to these elements when used without nitrogen.

Small White Spanish in the Florida variety-strain tests have been observed to produce relatively higher yields of peanuts in West Florida, than at Gainesville. In Table 1 the yields are expressed in percentage of Florida Runner, which is used as the basis of comparison.

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THE FIELD CORN BREEDING PROGRAM IN FLORIDA

Earl S. Horner*

One objective of the field corn breeding program in Florida is the development of improved hybrids which are well adapted to the local environment. Possibly a number of hybrids will be required. The ideal solution from the seed production point of view, however, would be a single hybrid which would be superior to all others anywhere in the State.

The purposes of this paper are to discuss the importance of hybrid-environment interaction, the methods that are being used, and the progress that has been made in the breeding of adapted hybrids.

HYBRID-LOCATION INTERACTIONS

The most striking example of specific adaptation within the State of Florida is seen in the corn variety recommendations on mineral soils in North Florida contrasted to those on organic soils in South Florida. At present none of the varieties or hybrids that do well in one section is at all satisfactory in the other. Two hybrids that were tested both at Belle Glade and in North Florida in 1953 serve as examples (Figue 1). Dixie 18 was consistently higher yielding (statistically significant) than Funk's G-737 at all three locations in North Florida, but was significantly lower yielding at Belle Glade.

We do not know what environmental factors are primarily responsible for such striking differences in adaptation. The latitude, which affects day length, is not a likely factor because other hybrids have been moved farther (North Carolina to Florida) with little effect. The two hybrids are of the same maturity, and insects and diseases did not appear to be important in any of the tests.

Other environmental factors are temperature, soil and moisture relationships, and cultural practices. Perhaps one or a combination of these is the cause of the differential response of Dixie 18 and Funk's G-737. Soil fertility alone may be important, as Harvey (1) found a significant interaction of inbreds and source of nitrogen.

Whatever the reasons, we do know that hybrid-location interactions exist, and our breeding program is organized so they can be allowed for in the selection of new hybrids. In North Florida most of the experimental crosses are tested at the North and West Florida stations as well as at the Main Station. We are also cooperating with the Everglades Station in developing a suitable variety or hybrid for that area. In the latter situation breeding material of a more tropical origin is being utilized than in the North Florida program.

SYSTEMS OF BREEDING

A breeding technique called "recurrent selection" by Hull (2) is being used in selection for yield and other characters in the Florida program.

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In this system the best 10-20 lines or plants available are interbred to form a closed population which is the basis of further selection. In each succeeding cycle tests are made to determine the superior plants (or S$_1$ lines) which are themselves intercrossed to form the basis of the next cycle. This method provides for a gradual concentration of genes favoring the character or characters under selection.

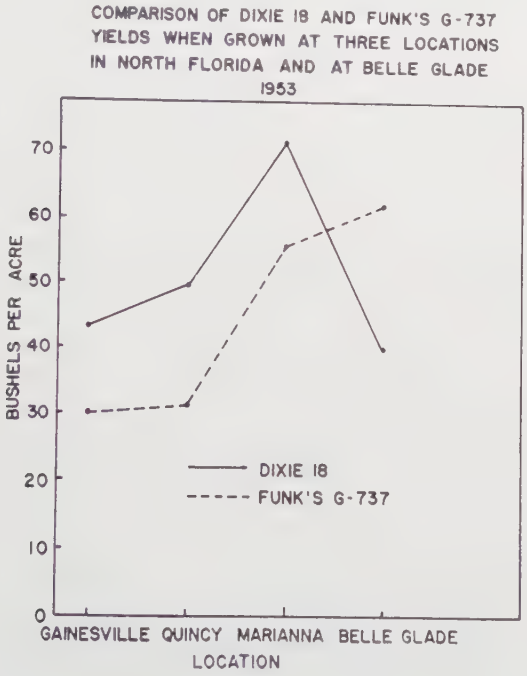

Figure 1.

A number of researchers have reported favorably on recurrent selection as a breeding method. Among these are Sprague and Brimhall (5), who found, in selection for high oil content of the corn kernel, that recurrent selection was at least 2.6 times more effective than selection within and among inbred lines. Johnson (3) and Lonnquist (4), working on sweetclover and corn, respectively, also have had good results using this method in selecting for yield.

PROGRESS TO DATE

The most advanced phase of the program in North Florida is the one in which we are selecting for combining ability with the single cross F^{44} x F^{6}. The distribution of the 528 second cycle test cross yields at Gainesville and Quincy in 1952 is shown in Figure 2. The yields ranged from 29 to 59 bushels per acre with a mean of 45.2. Dixie 18, which was planted every tenth plot as a check, averaged 47.8 bushels per acre. Twenty-five of the best crosses, which were selected on the basis of stand-

ability and weevil resistance as well as yield, averaged 52.3 bushels per acre. The lines which were the pollen parents of the selected crosses were interbred to make up a composite which is the basis of the third cycle of selection.

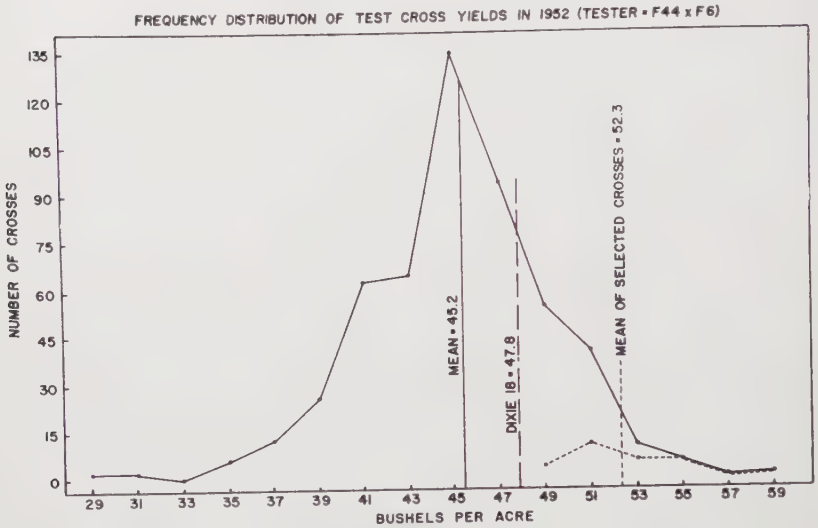

Figure 2.

The 25 selected crosses were retested in 1953 at Gainesville. As a group they averaged 43.6 bushels per acre compared to 43.7 for Dixie 18.

The failure of this select group to exceed Dixie 18 in yield in 1953, as it did in 1952, may have been caused by two factors—chance variation and season-hybrid interaction. It is possible that hybrids of average yielding ability may have appeared superior in this test by chance alone, even though six replications were grown. Also, the various hybrids may have responded differently to the 1953 season than to the 1952 season.

Since the 25 selected crosses from the second cycle averaged 4.5 bushels per acre more than Dixie 18 in 1952 and almost exactly the same in 1953, it seems reasonable to expect that the average of all the test crosses in the third cycle will be about equal to that of Dixie 18. If this proves to be true it will mean a gain of about six percent in yield for one cycle of breeding. The selected crosses in 1954 should be proportionately higher yielding than those selected in 1952.

DEVELOPING NEW LINES

New inbred lines which transmit high yields and disease and insect resistance to their progeny are badly needed.

In isolating new lines we find that comparatively low yielding test crosses are the rule in the initial stages. This is not surprising considering that our standard commercial hybrids are made up of only a few lines selected from thousands.

Two experiments which were conducted at Jay, Quincy, and Gainesville in 1953 will serve as examples. Sixty new lines were crossed to the inbred line F^6 and another 60 to the composite 767. Of the entire group of 120 test crosses, none equalled Dixie 18 in yield (Figures 3 and 4). These data indicate that the development of desirable lines is a rather slow process. Probably it will take several cycles of selection to accumulate enough favorable genes in the new lines to make them valuable commercially.

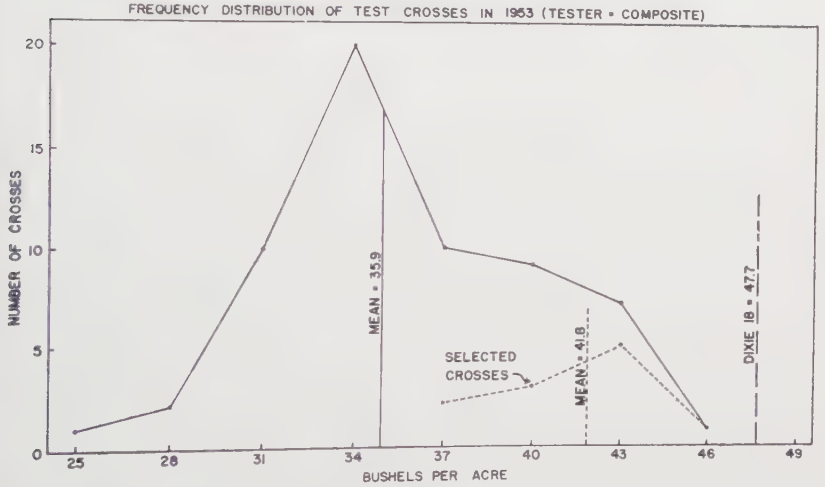
FREQUENCY DISTRIBUTION OF TEST CROSSES IN 1953 (TESTER = COMPOSITE)
NUMBER OF CROSSES
BUSHELS PER ACRE
MEAN = 35.9
SELECTED CROSSES
MEAN = 41.8
DIXIE 18 = 47.7

Figure 3.

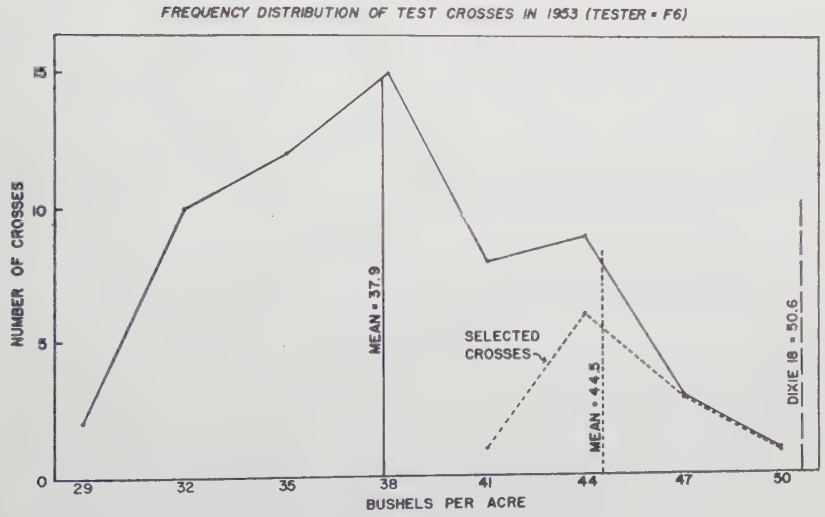
FREQUENCY DISTRIBUTION OF TEST CROSSES IN 1953 (TESTER = F6)
NUMBER OF CROSSES
BUSHELS PER ACRE
MEAN = 37.9
SELECTED CROSSES
MEAN = 44.5
DIXIE 18 = 50.6

Figure 4.

SUMMARY

The necessity for developing corn varieties and hybrids adapted to specific environments is recognized. Ideally, a single variety or at most a few varieties adapted to wide areas is the most desirable situation, in order to avoid confusion in selecting the one to grow. Evidently at least two are needed in Florida, one for the mineral soils of North Florida and one for the organic soils of South Florida.

Progress in the development of improved hybrids is slow, but there is evidence that hybrids superior to those now in use can be developed by means of the recurrent selection technique.

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SOILS PROBLEMS CONFRONTING THE TOMATO BREEDING PROGRAM

James M. Walter*

There is little doubt that the work in which several of us in Florida are engaged in trying to breed improved tomatoes with resistances to all of the important diseases brings us face to face with many of the unsolved problems with which soils scientists are concerned. One of the intriguing aspects of the painstaking work that must be done in efforts to evaluate our selections is that we observe many unexpected reactions for which we can call forth no immediately plausible explanations. As you can readily understand, it is seldom possible for us to pursue these questions to satisfactory ends; therefore, in the following statements I shall be presenting observations and ideas more often than facts.

Perhaps the most complex and costly problem facing us in tomato breeding is local adaptation: the hard fact is that, in most cases, a new tomato selected for high yield in one location proves inferior when planted as little as 100 miles away. This is general experience with the tomato and certain other important crop plants. Many of you have heard of the STEP trials, which have been in operation for a number of years and have meant the organized testing of promising new tomatoes at an average of about 25 experiment stations in the southeastern states. The record to date, with roughly 200 entries tested, is that only one has shown promise of the wide range of adaptation characteristic of the variety Rutgers. And it turns out that this entry is not a fixed type! Suffice it to say that we now know that it is impossible to judge the utility of a new product of our breeding program on performance in a few trials in a few locations.

When we are confronted by unexpected reactions of our new fixed lines as we observe them in trials it is very difficult in most cases to decide whether the prime factor is one having to do strictly with soil and nutrition or one having to do with climate, such as temperature or light. At present I am hoping that trials of some of our new tomatoes in hydroponics gardens in several sections of the State simultaneously with field trials in the same areas will aid us to reach the proper conclusions about some of these questions. It is obvious that many of our best selections turn out to be physiologically fixed in their ways when they have reached the F_6 or F_7 generation. STEP 160 is an example of a type with many excellent features but a limitation rather clearly due to temperature. For three years in succession this line was the outstanding item in our fall-crop trials, and it always showed striking ability to develop fruits of excellent size and quality during December and January. Moreover, when grown as a winter crop at Homestead it showed good producing capacity. Eventually we noticed, however, that, with all controllable soil conditions favorable for the development of tomato fruits, this line failed to make fruits of acceptable size after the weather became hot in April. As you may surmise, the record of STEP 160 at Gainesville and locations farther north was poor.

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It has been observed repeatedly on the fields at the Gulf Coast Station that a tomato line produces considerably larger fruits when grown on light sand than when grown on the sandy loam tracts containing enough degenerate organic matter to produce the sticky soil that we call gumbo. There are exceptions to this rule, the variety Manasota perhaps being the most notable.

Another reaction properly considered a soils problem on which we find our fixed lines definitely different is blossom-end rot. Manasota is clearly susceptible to this trouble, but Manalucie appears to be resistant. The same holds true, it seems, for crease-stem. Still another unsolved problem that may be due to nutritional imbalance of a temporary nature is cat-facing. Some of our most important varieties and selections are very susceptible to this costly disorder.

Frequently we observe startling differential reactions to soils problems of which we have no understanding. An example of this type that left a lasting impression on me occurred last spring in an experiment in which we were trying to collect data on the interaction between tomato variety and fertilizer practice. The tract of sub-irrigated Bradenton fine sand we used for the experiment had produced fine crops of tomatoes in 1946 and 1949; but we suspected that something had gone wrong with the soil because it had not produced a satisfactory crop of corn, tomato, sesbania or anything planted on it since 1949. The tomato varieties and lines planted on this tract for our experiment last spring included Rutgers, Jefferson, Homestead, Manasota, AStW 60, V.C.L. No. 7, V.C.L. No. 11, and Manalucie. All of these tomato stocks did well until the week following the first harvest, the first picking from each stock being of good quality. All at once, with the exception of Manalucie, the plants lost color and turgor and their fruits became flabby, without respect to fertilizer treatment. The Manalucie plants proceeded to produce a high yield of excellent quality fruits. This result is taken as evidence that Manalucie is somehow able to obtain needed nourishment that the other varieties and lines cannot obtain, but we have no information concerning any particular deficiency or excess applying in this case. All available evidence, of course, indicates that Manalucie is a strong feeder and is going to prove widely adapted.

During the past eight weeks we have been baffled by the failure of one of our early, prolific, new fixed types to size its fruits on 9 fields in the Ruskin area. On two fields in the same small area the stock has given high yields of fruits of desirable size for market. We have for these 11 fields the most complete record ever kept on commercial plantings, including soils sampling data from frequent planned samplings made by Dr. Geraldson and including complete records on soils conditioners and spray materials applied. These data give us no clue to any explanation of why the tomato line failed in 9 out of 11 of the fields.

The responses of tomato in general to the major fertilizer elements are reasonably well known, and I need not elaborate them here. As you are all aware, we have known since the classic work of Kraus and Kraybill some 25 years ago that the proper way to manage the feeding of a tomato crop is to keep the plants a bit hungry until they have set two hands of fruits and then feed them generously. Moreover, its stands to reason that the best controlled feeding of tomatoes grown on light sand, as is most of the commercial acreage in Florida, is by frequent light applications

of fertilizer. Many of the growers, however, fail to recognize the importance of this point, and, because of the convenience, proceed to give their crops too much fertilizer while the plants are young. I am firmly convinced that many of the growers' difficulties stem from this practice. Another of my convictions is that the tomato should be fed generously with potassium if it is to produce its best qaulity of fruits and show its best resistance to certain important diseases such as bacterial spot and early blight.

The bulk of the acreage of tomatoes in Florida is grown on newly cleared sandy land, the tomato grower cooperating with the cattleman to the benefit of both. Obviously, there will eventually be an end to the frost-free and otherwise suitable new land. Thus, a prime objective of the tomato-breeding program is to develop varieties that will produce good crops on old sand land. It is true, of course, that minor-element deficiencies are problems on new land as well as old, but on the basis of experience in the Bradenton-Ruskin area, we expect them to become more troublesome and numerous as the sands are repeatedly cropped. Thus the new tomato for satisfactory production on old sand lands must be an able feeder, such as Manalucie seems to be.

It is a common observation that the tomato plant grown on old sand fails to develop a sufficiently extensive root-system but that no pest can be found damaging the roots. At present we think of this as an unexplained physico-chemical problem; but we do have tomato stocks that are exceptions to the rule. Certain breeding stocks of interest for resistance to nematodes proceed in much-used sand to make roots as long as those of the variety Grothen's Globe growing in first crop sand. One breeding stock of the Manahill class that we consider important among our long list of stocks is outstanding only because it produces long roots on old sand tracts.

There are two troublesome diseases of tomato in Florida caused by organisms that are native, i.e., present in land that has never been cropped before. These diseases are bacterial spot and sclerotiniose, and at present it seems doubtful that we shall ever find effective hereditary resistance to them. However, the list of soil-borne diseases of tomato that may become important after the land is used once or twice for the crop is much longer. This list includes Fusarium wilt, Rhizoctonia, Southern blight, black-spot, early blight, buckeye-rot, bacterial wilt, root-knot, and other diseases due to nematodes. Progress has been made in breeding tomatoes for resistance to certain of these diseases; but I can assure you that much remains to be done, and that we shall need much more knowledge about the problems from the soils science standpoint before we can hope to accomplish the objectives toward which we are striving

A BRIEF SUMMARY OF SUGAR CANE BREEDING IN FLORIDA — 1930-1953

THOMAS BREGGER*

The discovery of mosaic, which caused great reduction of sugar production in the early 1920's, led the USDA to establish a sugar cane breeding station at Canal Point, Florida. At that time there was no commercial production of sugar in Florida. Naturally, most of the work at Canal Point was carried on to help the Louisiana sugar industry. The first reported crop of sugar in the Everglades of Florida was that of 1928-29 by the Southern Sugar Company. Most of the varieties were adapted to the mineral soils of tropical regions and were suitable here only on the warmer, more highly mineralized soils near Lake Okeechobee. One of those tropical canes, POJ 2725, is still grown to a limited extent on the warmer custard apple soils. Another variety which had been grown to a limited extent was CO 281. This cane had a reputation for early maturity in the tropics. It may be considered a sub-tropical variety. These two varieties played an important role in the breeding work in the Everglades because they are the parents of two varieties that have until lately been the chief producers of sugar in this area.

In the early days of cane breeding at the Everglades Experiment Station, most of the parents were the "POJ" canes, (that is, canes from the Proefstation Ost Java in Soerabaja, Java), canes from Coimbatore, India, known as "Co", and Canal Point or CP canes which in turn were derived mostly from POJ's and Co's. The POJ canes carry the resistance to mosaic. Earliness is derived from the Co canes. Varieties which produce no pollen are used as females, and pollen-producing canes are males. Owing to this male sterility, it is impossible to make certain crosses. One way out of this difficulty is to cross these pollen-sterile individuals to a pollen-bearing cane and crossing selections from these combinations in the next generation. In the course of the years it had been found that in certain years when the weather is not so cold, these male steriles produce some pollen so that they may occasionally be used as males.

The actual procedure at the Everglades Experiment Station is to tie from 2 to 6 male tassels around the female tassel in the field. The male tassels have from 3-5 feet of cane attached and are held in quart jars of approximately 1 to 3000 solution of H_2SO_3. The liquid in these jars is replenished every day. In a week to 10 days a second batch of tassels is tied around the female tassel.

Until 1947 all of the crossing work was carried out at the north end of Kreamer Island in Lake Okeechobee where frost damage is at a minimum. The male tassels were from canes grown at Bryant, Florida, on land of the USSC. Since then, a breeding garden planted to female varieties has been established at Lake Worth Farms on Lawrence Road about 2 miles west of Hypoluxo, Florida.

Usually a month to 6 weeks from the start of the crossing is required for ripening of the seed. The ripe tassels are collected in paper bags and

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kept in the laboratory for 3-5 days and then sown on the surface of previously sterilized flats of peat soil in the greenhouse. Sterilization is accomplished by applying 25 cc. of 40% formaldehyde in a gallon of water. Bottom heat is preferable, but, since it is not available, the greenhouse is kept well closed to maintain a high temperature and supplied with plenty of moisture by frequent watering during the day. In times of plenty of sunshine the seeds commence germinating in 3 days. In cold cloudy weather, as much as a week to ten days is required. The seedlings are kept growing in the greenhouse until frost danger is over and then clipped to about 3-6 inches and placed out of doors to "harden off". They are transplanted directly from the flats to field. The field is leveled and then wetted down with 3-4 inches of water by means of overhead irrigation. They are dibbled in about 2 feet apart in the row and watered with about a half-inch of water daily for the next three or four days. After that they get no further care except weeding and 300 lbs. of muriate of potash per acre.

A few selections may be made in the fall of the first year, but usually the cane is stubbled and selections made the second year. The most vigorous stools with a large number of millable canes of good length and medium diameter are sought. They should not have adherent sheaths and should show a minimum of leaf diseases. When a desirable appearing cane is encountered, a juice sample is taken to determine the Brix, or total soluble solids, by means of the hand refractometer. If they fall to far below the standard varieties in this respect, they are not saved unless they show some other characteristics that make them desirable in the breeding program. All selections are planted in 20-foot line tests with every 10th row a standard variety. If sufficient material and land are available, duplicate or triplicate rows are planted at the Everglades Experiment Station and at other places.

The method used by the United States Sugar Corporation and USDA are essentially the same as those used at the Everglades Experiment Station. These two use the Hawaiian solution, which contains 150 ppm. SO_2 and 85 ppm. H_3PO_4 for maintaining the male tassel. Each breeder uses different parents in his crossing work. Most of the breeding stock and commercial canes trace their lineage to the POJ canes. These canes are vigorous and medium to large barreled, the latter of which occur in the 2nd or later back crosses of *Saccharum officinarum* L and *S. spontaneum*. The latter canes are thin and carry resistance to mosaic, but are poor in sugar. *Saccharum officinarum* has 80 chromosomes. *S. spontaneum* has been reported to have from 54 to 128. According to Bremer (3) the cross between clones of these two has produced seedlings with 80 to 156 chromosomes. Bremer explains the increase in these selected hybrids as due to doubling of chromosome numbers during fertilization. S. Narayanaswami (4) seems to think that doubling occurs at the time of egg production. These possibly triplopolyploids seem to be the canes we are looking for. In general it has been the experience of the author that these very vigorous large barreled cane are low in sugar. With no cytological studies available it has been the plan of the author to cross F31-962, a thin early sweet cane, with the large barreled late canes. Backcrossing these to F31-962 has not produced any large barreled sweet cane in his cultures up to now. Nevertheless, very promising material has appeared. It is hoped that by a combination of backcrossing and

intercrossing of selections derived by crossing from these selections, a more vigorous large barreled cane with early sweetness, resistant to cold, to mosaic and other diseases and insects may be discovered.

Since 1930, when cane breeding was started at the Everglades Experiment Station, over 300,000 seedlings from various parental combinations have been set out in the field and grown to maturity for at least one year. They have been examined at least once for presence or absence of both leaf and stem diseases and rated as to vigor and other agronomic characters. About 2500 have been selected and planted in line tests where they have been analyzed for sugar content for at least two years. Up to 1916 the line tests have been interplanted with a variety which tolerates mosaic to bring about natural infections of those susceptible to the disease. Since 1919 we have been sending the most promising canes to the USDA sugar cane station at Houma, La., for artificial inoculation with a mixture of the A, B, and D strains. Since 1952 we have been making artificial inoculations at the Everglades Experiment Station of young seedlings in the flats with a mixture of the mosaic strains D, B, and E known to occur in Florida.

No artificial inoculation methods have been used for the other diseases (2) present in Florida. Seedlings that are very susceptible are eliminated during the course of line tests, observation, and increase plantings. A certain amount of the two helminthosporia, Eyespot, *H. sacchari* Breda de Hahn and Brown stripe, *H. stenospilium* Drechs which are always present, serves as a source of natural infection. Brown Spot, *Cercospora longipes* Butler, Pokah Boeng, *Fusarium moniliforme*, Sheldon, Red Rot, *Colletotrichum falcatum* Went, Red Stripe *Bacterium rubrilineans* (Lee, Purdy, Barnum and Martin) and Root rot, *Pythium arrhenormanes* Drechs, are occasionally found. Ratoon stunting, a virus disease, has been recently found in Florida. It is especially damaging under poor growing conditions. We become aware of these latter diseases when seedlings susceptible to them occur in our cultures.

About 350 selections have been planted in increase and observation plots at the Everglades Experiment Station and on the sugar plantations. Further sugar analyses, as well as observations as to the amount of disease, vigor, and the ability to ratoon or stubble have been carried on with these clones. From all these seedlings only 6 selections are to be found in commercial production. These are F31-407, 436, 762, 962, F36-819 and F40-96.

F31-407 is a chewing cane with about 60-80 acres grown by one planter in the Everglades. This cane is a "muck" cane. We have this information from several persons who have tried unsuccessfully to grow it on mineral soils. F31-436 is a mid-season-to-late cane. One of its parents is POJ 2725 mentioned above. The discovery of F31-962, a seedling of Co 281 mentioned previously, advanced the grinding season from the first week in December to the first week in November or occasionally the last week in October. It is a thin, high fibered cane, but early in sweetness. The bulk of the sugar produced in the Everglades since 1938 has been from these last mentioned varieties.

F31-762 is a syrup and forage cane that is grown throughout the state on mineral soils. F36-819, a seedling of F31-962 x POJ 2878, is not an early cane. About 2,500 acres are grown on the shallow muck at the edge of the muck area west of Fellsmere. About 1,700 acres of F40-96

are grown commercially in the Everglades. It is sweeter than F31-962 but produces slightly less cane per acre. It has not been increased any further. It seems to suffer less from cold than F31-962 on the colder lands more removed from Lake Okeechobee. With the recent application of restrictions on acreage, the chances are that it may be dropped. F40-96 seems to be very susceptible to ratoon stunting disease, perhaps a more potent reason why it eventually will be dropped. The USDA has evaluated many seedlings in the field at Canal Point since establishment of CP 34-79. This is an early, high-fibered cane of which there are about 3,600 acres growing at Fellsmere on sand land. There were nearly 2,000 acres of this variety growing in the Everglades at one time because of results of a replicated trial which showed it to be as sweet as F31-962 with higher tonnage. However, the commercial mill results did not support its replicated plot test expectations and today very little of this cane is grown on muck lands.

The research division of the United States Sugar Corporation has been producing seedlings from crosses since 1934. Three of its seedling selections have recently come into commercial production. These are Cl. 38-32, 41-142 and 41-223. Cl. 41-142 is an early sweet cane, of high tonnage, low fibre and medium to thick diameter. It is reported not to ratoon or stubble very well, being unable to survive repeated freezes which occur in the colder areas more removed from Lake Okeechobee. Cl. 38-32 is a thin, midseason cane of high quality. It is disliked by some field men because it requires more weedings due to its erectness and consequent later closing in. Cl. 41-223 is a medium-barrelled cane, of medium to low fibre, of high tonnage, and medium as to earliness. It seems that it may replace F31-436 within a few years unless it shows susceptibility to the ratoon stunting disease or presents insurmountable difficulties in the factory. So far all three are free of mosaic and have suffered only to a limited extent from Brown Stripe and Eye Spot. Some Red Stripe, *Bacterium rubrilineans* was found on Cl. 41-223 during the 1952-53 season but apparently with no serious effect. CP 34-79, Cl. 38-32 and F31-962 are resistant to the sugar cane borer *Diatraea saccharalis* (F.). All the other varieties are considered susceptible to the cane borer.

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THE DEVELOPMENT OF NEW VARIETIES OF TABLE LEGUMES FOR PRODUCTION IN FLORIDA

A. P. Lorz*

INTRODUCTION

Little more than a summary of activities suggested by the title can be presented in the short space allotted here.

The table legumes, considered from the standpoint of the production of better adapted varietal types for the various cultural areas in Florida, are snap beans, lima beans, English peas and southern peas.

SNAP BEANS

In the field of snap bean improvement, release of new types of green bush snaps from the Florida stations has been greatly discouraged by the class of competition set up by such excellent new releases as Contender, Wade's Bush, Top Crop and Tenderlong 15, but the new variety Seminole, a Tendergreen type developed cooperatively by the Everglades Experiment Station and the U.S.D.A. Southeastern Vegetable Breeding Laboratory at Charleston, S. C., promises to give them serious competition (4). Among the breeding lines at Gainesville are several horticulturally superior but mosaic-susceptible types which are being used as breeding stocks in crosses with mosaic-resistant types in an effort to combine resistance with these superior horticultural attributes.

Out of a cross between Streamliner and Cherokee Wax has come a very promising wax bean tentatively designated Florida 101 (Figure 1) which seems to have captured some of the best attributes of both parents. Increase of this item has just been started and there has not yet been enough seed available for large-scale testing. It is therefore too early to state that this will be the substitute or alternate for Cherokee Wax which the horticultural characteristics suggest.

In pole bean breeding the most notable contribution is the establishment out of a cross between Pinto No. 5 shell bean (rust resistant) and No. 191 (commercial pole snap type) of several lines which combine the rust-resistance of the Pinto No. 5 type with the horticultural characters of the No. 191 type. The new rust-resistant commercial pole bean type is somewhat earlier and more productive (attributes of the Pinto No. 5 parent) than the present No. 191 commercial variety. Increase and large-scale tests are currently underway and release should be possible within the next year, probably not later than the fall of 1955. The original crosses resulting in the establishment of these lines were made at the Main Station but the principal part of the work involving selection from segregating material under rust-prevalent conditions and subsequent inbreeding and purification was done at the Gulf Coast Experiment Station and that Station has conducted the preliminary increase and testing.

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Figure 1. Fla. No. 101 wax bean breeding line from the cross Cherokee Wax x Streamliner.

Another pole bean (Fla. 501—Figure 2) out of a cross between Stringless Blue Lake (green-podded) and Blue Victor (purple podded) has vivid purple pods which are stringless, succulent and of good flavor. The purple color of the epidermis is not objectionable, for it is unstable and disappears upon cooking, thereby exposing the underlying green color. This is among the earliest of pole beans and a good yielding type but, if released, may be desirable only as a home garden type, for the tenderness of the pods seems to be responsible for comparatively rapid post-harvest deterioration of the fresh product, lack of firmness after prolonged cooking, and lack of firmness upon cooking the blanched and frozen pods. This would render it unsuitable for the fresh market (except local), for canning, and for commercial—but not home—freezing.

Recently a new development in commercial snap bean production threatens a mild revolution in the industry and may ultimately render economically unsuitable some or all of the several excellent varieties which are the basis of present commercial production. The mechanical bean picker (1), though not yet perfected, is a reality to be reckoned with. Either it will have to be further refined to handle efficiently the currently available types or the plant breeder must face the challenge to produce new, horticultural desirable types with plant habit characteristics which render them suitable for efficient mechanical picking. The prime attributes needed, in addition to the usually sought-for disease-resistance and horticultural quality and appearance, are: (1) determinate habit resulting in a large percentage of the pods reaching marketable maturity at or near the same time, for repeated pickings are not feasible with the

present machinery; (2) pods borne high and spread out over the plant so that the action of the picking fingers is not hampered by dense clusters of pods; (3) sturdy erect bush type plants which will not fall over with a load of pods and, (4) and—especially for the loose soils of Florida—a root system which will keep the plant from being uprooted during the picking operation. A fifth attribute in the form of an easily broken abscission zone at the base of the pod would also conceivably help the picking operation.

Figure 2. Fla. No. 501. High quality purple podded home-garden type pole bean.

Variety Vilmorin No. 1 seems to have most of the plant habit characteristics considered desirable for mechanical picking. Crosses have been and are being made between this and the better horticultural varieties and breeding lines in an effort to impart to the Vilmorin No. 1 type the freedom from strings and the lower fiber content which it lacks and which may be supplied by the better ones of our currently available bush varieties.

LIMA BEANS

With lima beans the chief objective has been to produce basic types comparable to the standard Fordhook and Henderson varieties, but with better ability to set pods under adverse conditions. Dry conditions and high temperatures encourage flower and pod abscission and our efforts to overcome this promise to be rewarded by the achievement of a new.

basically Henderson type which, in early non-replicated comparisons, has yielded much more abundantly than that standard. There are also available several promising Fordhook-type selections which need to be further compared to the standard before any statements can be made about them.

SPECIES HYBRIDIZATION

The quest for new sources of genes from other species than the common beans *Phaseolus vulgaris* L. and *Phaseolus lunatus* L. has also been an integral part of this work. At the Main Station we have crossed *Phaseolus vulgaris* with the following other species:

Phaseolus coccineus L., the Scarlet Runner Bean
P. coccineus albus, var. Barteldes Bush Lima
P. polyanthus Green.
P. glabellus Piper

In addition we have had access to material from the crosses *Phaseolus vulgaris* x *P. mungo* (the urd bean) and *P. vulgaris* x *P. lathyroides*, both by A. B. Strand (3). Likewise, in the cross between the Fordhook type lima bean, *Phaseolus lunatus* L. *macrocarpus* and the native wild Thicket bean *P. polystachyus* L. (Figure 3) we can claim the first authenticated instance of an interspecific hybrid involving the lima bean as one of the parents (2).

Figure 3. Seedlings from parental types compared with that of the F_1 hybrid from the cross *Phaseolus lunatus* (Fordhook type lima) x *P. polystachyus* (Thicket bean). Left: Parental types illustrating the respective epigeal and hypogeal positions of the cotyledons in *P. lunatus* and *P. polystachyus*. Right: F_1 hybrid with hypogeal cotyledons. Portion of soil removed where necessary to expose the cotyledons for photographic purposes.

Out of all these species crosses partial or nearly complete sterility and the failure to obtain large F_2 generations have been a partial deterrent to further exploitation but, in most instances, it has been possible

to backcross the F_1 hybrid to the commercial type bean. Material derived from three of these interspecific crosses is being watched with interest.

In the lima x thicket bean cross, where one of our objectives has been to incorporate into commercial limas the hypogeal germination habit of the wild bean, we have succeeded in reducing the cotyledon height to about one-third that of the Fordhook lima but we are yet a long way from completely arresting the elongation of the hypocotyl. More backcrosses to the wild thicket bean will be necessary before we can hope to achieve a commercial large seeded lima type which will not be susceptible to mechanical injury in attempts to raise the large and heavy cotyledons out of encrusted or impacted soils.

ENGLISH PEAS

Our efforts to produce better adapted English pea varieties for Florida constitute an attempt to revive a once thriving but now dying industry. We have to face up to the fact that frozen packed peas come close to duplicating the quality of the freshly picked product and the housewife is spared the trouble of preparing them for cooking. Many people, however, recognize either real or fancied differences which cause them to prefer peas in the pod over shelled peas in a package. For this reason there is still a limited but not inconsiderable demand for a good quality, market-type pea which Florida can supply during the off-season for the North. Commercial processors have indicated an interest in a freezing type pea for Florida, although they do not consider entering into serious competition with the Wisconsin producing area; for such a pea could be the basis of plant operation maintenance to fill in the lulls between other processing operations on fruits and vegetables.

We have numerous purified lines representing potential new varieties. However, the mechanics of testing and increase prior to release are a bottleneck in this program, because of the demands on time, space and personnel, and of other facets of our over-all program. One of these lines originated by selection as an off-type out of the heat-tolerant variety Wando and has longer pods than the type. It is an outstanding yielder of good quality peas. The other line, a product of the now discontinued pea breeding research at the U.S.D.A. Southeastern Vegetable Breeding Laboratory, we are attempting to build up and sponsor for release as our part of a cooperative effort. This pea, designated P-84, is a good but not outstanding yielder. The quality is outstanding and there are indications that retention of quality after picking is better than average.

SOUTHERN PEAS

There are several reasons why breeding research on culinary varieties of southern peas (*Vigna sinensis*) has recently begun to receive some of the emphasis it deserves. From the plant breeder's standpoint this is practically a virgin field. There is a wealth of diverse genetic material available, the crop is self-fertilized in nature, two generations a year are easily possible, and the reproductive potentialities from a single plant are considerable. From the standpoint of economic potentialities this is also a virgin field in view of the mathematically considerable number of yet unexplored and unexploited phenotypic combinations of the char-

acters available. Only comparatively recently has the superior quality of the white or cream-seeded types come to be more generally appreciated. The currently small-scale commercial freezing of this product gives promise of expansion possibly into the northern markets because the peas have no strong flavor nor do they have a black eye, either literally or figuratively. Unless plant breeders can develop one or more very early determinate varieties which do not go vegetative under the influence of the long summer days in the North, there is no fear of competition from that quarter. The South, therefore, should be able to maintain a monopoly on production and the South's current monopoly on consumption might be dissipated with the introduction into the North of a superior product, now available but in need of promotion.

The program at the Main Station was inaugurated with the expansion of a promising introduction from Korea for intended release. The Korean Crowder, as it has been called, excels in vegetative vigor and horticultural pod characters but proved to be too susceptible to several diseases, so that the release of this item has been abandoned, but it has already proven itself to be an excellent breeding parent in crosses where disease resistance has been provided by the other parent.

Numerous promising types are emerging from this research and several are uniquely different from standard types, suggesting wholly new possibilities in the production of dry bean and snap bean types as alternates or substitutes for the true beans.

So far no blackeye type has emerged that promises any superiority over the standard blackeye varieties, but three other general types at present seem superior to any available commercial counterpart. Whether this apparent superiority is merely a manifestation of hybrid vigor which will be lost through further automatic inbreeding or whether it will stand the tests of time and statistical analyses remains to be determined.

One of these three is an early determinate white-seeded line No. 15.2.2,1 which was started with a single plant selection. From the progeny of this plant was harvested approximately 25 lbs. of dry seed. This is an indication of its productivity.

A second type designated as No. 16,10,2,2 resembles the excellent newly released variety Dixielee in all superficial respects except that the pods are longer. No yield comparisons have yet been made.

Two lines of a third type resemble the running Conch or White Acre varieties. These tend to be too vigorous vegetatively upon exposure to long days at a time when the plants have developed sufficiently to be capable of pod and seed production. Consequently, these should succeed best when planted for fall harvest, but can produce a fair spring crop if planted earlier than March 1 in frost-free areas. No. 6,4,1,1 is essentially an improved White Acre to be grown primarily as a fall crop. No. 6,4,4,1 is a medium sized white crowder, less productive than No. 6,4,1,1 but producing a larger and better appearing shelled pea and also, like its sister line, is primarily adapted to the shortening day lengths of late summer and fall.

CONCLUSION

The importance of the production of table legumes in Florida's agricultural economy can best be appreciated by consideration of their mone-

tary value, using the figures supplied by the 1952-53 Annual Fruit and Vegetable Report of the Florida State Marketing Bureau:

Snap beans	$20,225,000
Lima beans	706,000
Field (Southern) Peas	735,000
English peas—No estimate	
Total	$21,666,000

While these figures point up the current status and relative importance of the different table legume types, and some hint of future prospects may be gleaned from studying the statistics of previous years, it is hardly possible to predict what the future will establish as a result of increasing competition from frozen foods produced outside the South on the one hand, and by the production through breeding of new, better adapted and therefore more efficient table legume varieties. The plant breeder faces a challenge but the prospects of meeting it seem good and, in the case of Southern peas, particularly bright.

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HISTORY AND PRESENT STATUS OF WATERMELON IMPROVEMENT BY BREEDING

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The watermelon, *Citrullus vulgaris* Schrad., believed to be native to Africa and in cultivation for over 4,000 years, is presently world-wide in occurrence, but is generally more prevalent in warmer climates. Some attempts at watermelon improvement by pure-line selection were made by individual growers over 100 years ago, but the greatest advances from watermelon breeding work have been made since 1930. The introduction dates of some older varieties that are still listed in today's seed catalogs are of some interest, however: Bradford (prior to 1850), Georgia Rattlesnake (1870), Florida Favorite (1887), Kleckley Sweet (1892), Cole's Early (1892), and Tom Watson (1906). Numerous varieties were introduced during the period 1880-1910, most of them strains selected by individual growers for peculiar adaptations to local situations. Some of them, e.g., Tom Watson, came into general use.

Perhaps the first organized program for the improvement of watermelon was begun in the United State Department of Agriculture by W. A. Orton. From this work came the first vegetable variety specifically developed by hybridization for resistance to a plant disease (Fusarium wilt) (2). The variety Conqueror, produced in eight generations from the cross of the wilt-susceptible, edible variety Eden and the wilt-resistant, inedible stock citron, was released in 1911. Conqueror proved not completely wilt-resistant in some parts of the United States, and was lacking in other characteristics desirable in a high quality melon, so that it never attained wide popularity. However, it was utilized as a source of resistance in the varieties Iowa Belle and Iowa King. These were used widely in breeding lines in Iowa, California (wilt resistant Klondike lines), Florida, and elsewhere (Congo, Fairfax, and several promising unnamed lines from the Southeastern Vegetable Breeding Laboratory at Charleston, South Carolina all of which have Iowa Belle in their ancestry).

About 1923 J. T. Rosa at the California Agricultural Experiment Station initiated work on watermelon improvement. Rosa's primary contributions were in fundamental studies on the inheritance of various plant and fruit characters and the effecting of substantial improvements in uniformity of fruit shape, flesh color, and other internal qualities, particularly in the Klondike lines (6). The California program was taken over in 1930 by D. R. Porter, who made valuable contributions in the development of watermelon breeding techniques and was responsible for the release of several wilt-resistant Klondike lines (4) (5).

In 1924 the Iowa Agricultural Experiment Station began a program to develop wilt-resistant watermelons. From this program, under the direction of various leaders, came the wilt-resistant varieties Pride of Muscatine, Iowa Belle, Iowa King, Improved Stone Mountain No. 5, and

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Improved Kleckley No. 6. The most significant contribution of the Iowa Station was the anthracnose resistance incorporated in several African x Iowa Belle (and Iowa King) crosses that are the bases for any practical anthracnose resistance that is available in present-day varieties and breeding lines (1). Lines with anthracnose resistance were sent to M. N. Walker of the Florida Agricultural Experiment Station in 1936. Several years later Walker forwarded lines with this resistance to C. F. Poole at the Charleston Laboratory (Congo, Fairfax, and 51-27 all have anthracnose resistance from this source).

Investigations at the Watermelon and Grape Investigations Laboratory of the Florida Agricultural Experiment Station were begun in 1930. As the result of work by M. N. Walker, and later G. K. Parris, the varieties Leesburg (7), Blacklee (8), and Ironsides (3) were made available to watermelon growers. Although none of these varieties attained great popularity in Florida, the Blacklee has proved of value in some more northerly states. The most significant contribution of the Florida Station to improving watermelons by breeding has been the development of breeding lines incorporating anthracnose resistance and wilt resistance in horticulturally desirable types. A number of these lines were furnished the Charleston Laboratory in 1941 and have been utilized very successfully in the regional watermelon breeding program. Congo was developed from one of Walker's anthracnose resistant lines selected by inbreeding from an Iowa accession. Fairfax has in its ancestry both Leesburg and one of Walker's anthracnose resistant lines.

The Southeastern Vegetable Breeding Laboratory watermelon program was begun in 1936. Work there under the direction of C. F. Poole and C. F. Andrus has resulted in the release of the very popular Congo and the recently released Fairfax, as well as Ironsides and Dunbarton, which were joint releases with the Florida and South Carolina Agricultural Experiment Stations, respectively. The as-yet-unnamed line 51-27 from this Laboratory also appears to be a very promising melon.

Wilt-resistant watermelons have been introduced by several other agricultural experiment stations and private agencies: Hawkesbury (Hawkesbury Agricultural College, New South Wales, Australia), Georgia Wilt-Resistant (Georgia Station), Miles (Tennessee Station), Wilt Resistant Dixie Queen (Twilley Seed Company), Missouri Queen (Missouri Station), Calhoun Sweet (Louisiana Station), Purdue Hawkesbury (Indiana Station), and others.

A review of the objectives of the watermelon breeding projects currently underway at the various experiment stations in the southeastern United States—according to the most recent report from the Southeastern Vegetable Breeding Laboratory at Charleston indicates that most workers in the field are interested in the development of one or more varieties adapted to their area with both anthracnose and Fusarium wilt resistance. acceptable shipping qualities, and superior internal fruit qualities. The Charleston Laboratory is also emphasizing work on icebox melons and large, seedless hybrid melons.

The watermelon-breeding program of the Florida Station has objectives substantially similar to those of the other stations in this area. Perhaps, however, somewhat more emphasis is placed on early maturing melons in our program, since Florida melons are sold primarily on the early market and a difference of one week in maturity may mean the

difference between a successful and an unsuccessful crop season to the grower. Of lesser importance in the Florida program is the aim to develop higher quality, disease-resistant small-type melons than those currently being grown. No work is presently underway on the development of large seedless hybrid melons, but that area is viewed as a promising one for future work. The ultimate aim of the Florida watermelon-breeding program is the development of one or more varieties with prolificacy, early maturity, superior internal fruit qualities, acceptable shipping characteristics, and resistance to the major diseases of this area that cannot be readily and economically controlled by other means.

Fusarium wilt, caused by *Fusarium oxysporum* (Schlecht.) f. *niveum* (E.F. Sm.) Snyder and Hansen, is the most important disease on watermelons in Florida. Wilt resistance in watermelons is governed by multiple factors, mostly recessive, so that the development of resistant varieties has been a rather slow process, but resistance to wilt is now available in a number of varieties and breeding lines adapted to this area. Major sources of Fusarium wilt resistance available in Florida breeding lines include the variety Conqueror (through African x Iowa Belle crosses previously described), the variety Kleckley Sweet (the resistance in Walker's Leesburg was developed by pure-line selection in this variety), and the variety Hawkesbury (Blacklee was selected from a Leesburg x Hawkesbury cross). Undoubtedly other wilt resistance factors have also been unconsciously selected from other lines in the process of growing numerous successive crops on thoroughly wilt-infested soil. Paradoxically, almost all of Florida's watermelon crop is produced at the present with the non-resistant varieties Cannonball and Congo. With the introduction of better adapted wilt-resistant varieties these two leaders eventually will be supplanted.

Anthracnose, caused by *Colletotrichum lagenarium* (Pass.) Ell. and Halst., long has been considered a major watermelon disease in Florida. Seed treatment has been an important factor in reducing its incidence. The dithiocarbamate sprays have been effective in controlling its spread. Anthracnose resistance may relegate this disease to a minor role in the future. Resistance to anthracnose is governed by a single dominant factor (1) and is presently available in Congo, Farifax, and 51-27. The original source of this resistance has been described.

Downy mildew, caused by *Pseudoperonospora cubensis* (Berk. and Curt.) Rostow, causes serious damage to watermelons in some years. In other years it is unimportant. Resistance to downy mildew has been reported from several sources but attempts to incorporate resistance into desirable horticultural types have not been successful. The mode of inheritance of resistance is unknown. Work with cucumbers showed that physiologic races of the fungus exist, so that attainment of downy mildew-resistant watermelons may be very difficult. Dithiocarbamate and copper sprays currently are used for control.

Gummy stem blight, caused by *Mycosphaerella citrullina* (C. O. Sm.) Gross., is also of major importance on watermelon, especially in cool, wet seasons. No high degree of resistance to this disease is known although differences in the susceptibility of some varieties have been noted. Seed treatment has not been successful in controlling gummy stem blight, but the leaf-spot phase can be checked with dithiocarbamate sprays.

Since the Fusarium wilt fungus is predominantly soil-borne and persists in the soil for many years, it has had a marked influence on the pattern of use of watermelon land over the years. Fields have been located in more and more remote locations, increasing the costs of production and harvesting of the crop. On the other hand the use of virgin or relatively "new" land, dictated by the necessity of escaping Fusarium wilt, may have had some concomitant but unrealized beneficial effects. For example, minor element deficiencies or toxicities have not been problems in watermelon production.

Changes in land utilization practices as a result of the adoption of wilt-resistant varieties might conceivably, therefore, result in some new problems. Diseases hitherto of little or no importance might become major ones. Both the anthracnose and gummy stem blight fungi are known to be seed-borne. Both also are believed to be able to persist on plant debris in the soil from season to season. The relative importance of seed and soil as sources of infection has not been determined for these two diseases. Under cropping practices with non-wilt-resistant melons. the importance of soil-borne sources of infection has been negligible. With more intensive cropping of land to watermelons, both anthracnose and gummy stem blight might become more important diseases. Downy mildew is not known to be seed-borne and does not persist in soil-borne debris. However, it does attack other cucurbits (cucumber, muskmelon. squash, pumpkin, other wild species) and is known to persist throughout the year on living hosts in Florida.

No discussion of watermelon culture in Florida would be complete without mention of nematodes, particularly root knot nematodes (*Meloidogyne* spp.). While root knot trouble in melons has been minimized by use of virgin or relatively "new" land, it also could become a major problem for watermelon growers under more intensive cultural practices. No root knot resistance in watermelon is known.

When watermelons are developed in large, small, and intermediate sizes, in both round and long shapes, with early maturity, high yields, acceptable eating and shipping qualities, with and without seeds, and with resistance to all the important diseases, insects and nematodes, then the watermelon breeders' job will be essentially finished. Until that time he should have a great deal of fun attempting to attain those ends.

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VARIETAL IMPROVEMENT OF LUPINES FOR FLORIDA

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Lupines have been used as a cover crop in Europe for many years where they are grown as a winter cover in the southern areas and as a summer crop in parts of Germany and the Scandinavian Countries. They have recently been adapted as a cover and grazing crop to the states bordering the Gulf of Mexico. Some introductions into Florida, Georgia, and Alabama showed promise as early as 1930, although commercial production dates only from 1939. They have increased rapidly as a cover crop and with the introduction of alkaloid-free strains, have become important as a winter grazing crop. Lupines, blue and yellow, have now largely replaced all other winter legume cover crops in the Coastal Plain of the Lupine Belt.

There are many species of lupines, some native in the United States, both annual and perennial, but for agricultural uses, three annual introduced species are important in this area. Blue lupine, *Lupinus angustifolius*, yellow, *L. luteus*, and white, *L. albus*, are being grown successfully. These species have certain advantages which have raised them rapidly in popularity. They are vigorous, rapid growers, producing from 20 to 40 thousand pounds of green weight per acre. This heavy vegetation is easily turned under where it rapidly decays releasing nitrogen for such crops as corn, grasses, etc. Lupine seed germinate at a higher temperature than many winter cover crops, so that the plantings can be made earlier in the fall. This permits a longer growing season for heavy production of foliage to be turned under in February or early March. They produce heavy seed crops so the farmers can grow their own seed, thus reducing the cost of new seed.

Lupines also have some disadvantages when grown in this area. They are susceptible to winter killing. This is conditioned by a number of factors such as stage of growth, moisture, length of exposure, and species. However, many may stand short periods of 18° F. They are susceptible to nematodes and should not be used in rotation with highly susceptible vegetable crops, such as cucurbit and Solanum spp. Several disease organisms and insect pests may cause severe losses in seedling stands, reduce green weight, and lower seed yields. Many lupines tend to shatter when ripe, making harvest difficult. This results in harvesting immature seed with high moisture contents, which must be dried to insure good quality seed. Legumes will not make satisfactory growth without Rhizobium bacteria. Since the bacteria required to nodulate the lupines do not occur naturally in Florida soils, they must be supplied.

The first commercial plantings of bitter blue lupines appeared to have few insect and disease pests. However, as the acreage increased and spread involving widening environmental conditions and additional soil types, the insect and disease problems became more important. A

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number of the serious disease and insect pests described on lupines in Europe have only been observed in the United States in the past few years. However, by 1950, most European troubles were found damaging growing lupines in the Southern States plus a few more, native to this area.

Although the original introductions of blue lupine seed came from a limited area of Europe, wide variation occurred between individual plants when these seed were planted. Single plant selections grown in a plant-to-row nursery plot established many different types of plants as to flower color, seed marking, and insect and disease reaction. Certain of these characteristics, such as increased vigor, superior seed set and tolerance to disease pests appeared to offer promise for varietal improvement. One such selection was increased and released as Alta Blue. In the nursery and increase plots this selection was superior to the commercial bitter blue in green weight, seed yield, and appeared to be resistant to seedling damp-off and to damage caused by the lupine fly, *Hylemyia lupinii* (Coq.). Alta Blue grows well on heavy soils, but is not adapted to the light sandy-soils found in the Lupine Belt.

Florida No. 2 is a bitter blue selection from an Australian introduction. Under field conditions, especially on sandy soils, this selection has maintained better stands than either Alta Blue or commercial bitter blue. This indicates that it has some field resistance to seedling diseases, although under greenhouse trials, Florida No. 2 is susceptible to these seedling diseases. The plant type is short and more branched than Alta Blue and produces good quality seed.

All blue strains are susceptible to the lupine fly, while yellow lupines are not. There is, however, a related species reported as a serious pest on yellow lupine in Portugal. This insect, *Hylemyia cilicrura* Rond. although found in this country, has not become a serious pest.

Alkaloid-free or sweet strains isolated from the bitter blue seed stock have produced satisfactory seed crops and can be used for livestock feed in some areas, either as pasture or as protein supplement. European workers have found that the non-alkaloid characteristic is due to recessive genes which also reduces the vigor of the plant. The Swedish workers have introduced a strain of sweet blue, Borre, which has a wider adaptation, suggesting that the association of reduced vigor and non-alkaloid may have been broken in the breeding material.

Yellow lupine introduced into Florida about the same time as blue lupine was not grown commercially until 1945. Both bitter and sweet strains of the yellow species occur but the interest is primarily in the sweet strains. While considerable difficulties were experienced in maintaining pure sweet blue strains, the sweet yellow strains have been more stable in the non-alkaloid characteristic. Thus the sweet yellow strains offered promise for winter grazing and were in demand when the winter oat grazing crop was threatened with *Helminthosporium victoriae*. Non-shattering strains of sweet yellow were developed, which greatly increased the value of the crop as satisfactory seed crops could be combined by the farmers.

The white lupine is somewhat similar to blue lupine in plant characteristics except that the leaves are larger and the flowers are white and the seed are larger and flat. It is grown only in limited areas in Louisiana and the northern areas of the Lupine Belt.

Breeding for insect and disease resistance in lupines is limited as no species crosses has been successful. The blue lupine is rarely cross pollinated but the yellow lupines may be, especially if visited by bees when in flower. Crosses between both the sweet and alkaloid strains in each of blue and yellow have been made and their progenies grown in experimental plots. A search for disease and insect resistance in these hybrid progenies has offered a limited number of promising selections.

In Table 1. is a list of some of the diseases and insects that may cause serious damage to lupines grown in the Lupine Belt.

TABLE 1.—Disease and Insect Pests of Lupines.

Diseases	
Seedling troubles	
Damping-off	Rhizoctonia solani Kuehn
Southern blight	Sclerotium rolfsii Sacc.
Wilt	Fusarium spp.
Pythium root-rot	Pythium spp.
Growing plant	
Brown spot	Ceratophorum setosum Kirch
Anthracnose	Glomerella cingulata (Ston) S. & S.
Stem rot	Sclerotinia sclerotiorum (Lib) D By.
Powdery mildew	Erysiphe polygoni D. C.
Stem canker	Botrytis cinerea Fr.
Ascochyta canker	Ascochyta gossypii Syd.
Virus diseases	
Pea mosaic	Marmor leguminosarum Holmes.
Cucumber mosaic	Marmor cucumeris Holmes.
Shepard's crook	Not described
Nematodes	
Root knot	Meloidogyne spp. (Cornu) Goodey.
Insects	
Lupin fly	Hylemyia lupinii Coq.
Lupine maggot	Hylemyia cilicrura Rond.
Lesser corn stalk borer	Carposinidae
Plant lice	Aphididae
Spittle bug	Lepyronia quadrangularis
Thrips	Thysanoptera

Several virus diseases attack lupine in this country but only a few outbreaks of the disease were reported before 1950. Plants affected with a virus usually have numerous small branches along the stem with leaves and leaflets of one-third to one-half normal size. Some of the affected plants may show reddish or yellowish discoloration, with brown streaks down the side of the stems. Virus affected blue lupine plants are dwrafed and usually die prematurely, while virus affected yellow plants are stunted but may remain alive after the normal plants have set seed and matured. Several virus diseases of lupine have been described in Europe where they have caused moderate losses. An undescribed virus in the United States has caused serious losses to both blue and yellow lupine. Since blue lupines affected with this virus are readily killed, the field spread is limited; while virus affected yellow plants do not die, field spread may be rapid and extensive involving from 50 to 100 percent of the

plants. The affected plants may bloom, but set no seed. Breeding for virus resistance has produced yellow strains with a degree of tolerance which may produce as much as 20 thousand pounds green weight per acre, but very few seed. As the virus may be seed borne, only disease free seed should be used for planting.

Since varieties resistant to all of the disease and insect pests are not known, crop rotation combined with clean seed is recommended for keeping these lupine diseases in check. Proper seedbed preparation, insuring uniform planting depth is especially helpful in eliminating the seedling disease. This is because under favorable conditions the planted seed germinate readily, producing a strong plant that is better able to escape the seedling diseases. Brown spot, anthracnose and virus diseases may be seed-borne, so disease-free seed of good quality is recommended for planting. Chemical seed treatments have been tested extensively in Florida, Alabama and Georgia and none has been found that can be recommended.

The varietal improvement of lupines for Florida is aimed at developing disease and insect resistant varieties adapted to the soils and climatic conditions. There are many species of lupines that will grow in Florida, some are known to have considerable resistance to certain insects and diseases. Although species crosses in lupines have never been made, attempts have been encouraging. When these crosses are made, an expanding field in varietal improvement in lupine will be available. In the meantime, breeding within species will continue to produce useful material for agricultural uses as for example Alta Blue, Florida No. 2, non-shattering white, seeded sweet yellow and yellow virus tolerant strains.

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IMPROVEMENTS IN POTATO VARIETIES AND YIELDS AT HASTINGS, FLORIDA

A. H. Eddins and E. N. McCubbin*

During the last 16 years numerous potato varieties and seedling selections have been tested at the Potato Investigations Laboratory, Hastings, Florida, and their yields and other characteristics recorded (2). Some of the results of those tests and the effect of recent improvements in farming practices on potato yields at Hastings are discussed in this paper.

RESULTS OF POTATO VARIETY TESTS

Most potatoes are planted in the Hastings area from December 20 to February 1 and are usually dug 95 to 100 days after planting. The Hastings crop is sold as new potatoes and is dug when the tops are still green and the tubers are immature. The number of sacks of potatoes required to meet total crop cost per acre varies from year to year, depending upon the selling price of potatoes. In the 1951-1952 season it was necessary to produce 108 hundred-pound sacks of salable tubers per acre to pay cost of growing and harvesting the Hastings crop (1).

An acceptable potato variety must have the ability to recover and produce good yields at Hastings after tops of the plants are killed by freezing during early stages of growth, as severe freezes occur about once every four years. Resistance to diseases such as late blight (*Phytophthora infestans* (Mont.) D By.), common scab (*Streptomyces scabies* (Thaxt.) Waksm. and Henrici) and bacterial wilt (*Xanthomonas solanacearum* (E. F. Smith) Dowson) are important characteristics.

The tubers must be free from knobs caused by second growth and resistant to skinning and cracking during digging and handling and also browning. The most salable tubers are uniform in size and shape, have medium shallow to shallow eyes and are free from defects that impair their soundness or mar their appearance. The variety grown also must have good chipping qualities, as a third or more of the Hastings crop is sold to chip makers.

Within the last quarter century many new potato varieties have been created as a result of the cooperative potato-breeding work of the United States Department of Agriculture and several state experiment stations. New varieties and seedling selections found equal or superior to standard varieties in yield, quality and resistance to one or more diseases at the breeding stations are released to experiment stations in potato-growing sections of the country where they are tested to determine their adaptability to local conditions before being recommended for commercial production (2, 4).

Thirty-two varieties and 125 USDA seedling selections have been grown in replicated plots at the Potato Investigations Laboratory during

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the last 16 years. Yields of 14 varieties which have been grown commercially in the Hastings area are compared with those of the standard variety, Sebago, in Table 1.

TABLE 1.—Comparison of Average Yields of Sebago and 14 Other Potato Varieties Grown in Replicated Plots at Hastings, Florida, from 1938 to 1953.

Varieties	Number of Tests*	Hundred-Pound Sacks U. S. 1 Tubers per Acre		Yields Compared to Sebago**
		Variety	Sebago	
				Percent
Bliss Triumph	13	95	151	63
Cherokee	8	203	185	110
Chippewa	12	97	158	61
Earlaine	10	94	153	61
Essex	3	233	224	104
Green Mountain	4	107	162	66
Irish Cobbler	11	122	163	75
Katahdin	18	124	161	77
Kennebec	10	184	176	105
Pungo	6	185	190	97
Red Pontiac	8	207	175	118
Sequoia	11	165	154	107
Spaulding Rose	12	115	169	68
White Rose	6	138	191	72

* Each test consisted of 5 to 10 replicates of each variety planted in 25-hill, single-row, randomized plots.

** Varieties which yielded 61 to 77 percent of that of Sebago were significantly below it in yield. Yields of the other varieties did not differ significantly from that of Sebago.

Bliss Triumph, Chippewa, Earlaine, Green Mountain, Irish Cobbler, Katahdin, Spaulding Rose and White Rose yielded significantly less than Sebago in test plots (2). These varieties were displaced by Sebago at Hastings soon after it was introduced in 1941.

Small acreages of 5 varieties whose yields did not differ significantly from that of Sebago in test plots were planted by a few growers and dropped after 1 to 2 years.

Cherokee and Kennebec are highly resistant to late blight and produced good yields at Hastings. However, shipping and chipping tests showed that both were more prone to develop mechanical or handling damage, scald spots and decay than Sebago and did not produce chips equal in color to those of Sebago (3).

Pungo is not adapted to commercial production at Hastings, as its tubers are irregular in shape and develop second growth when rainfall is unevenly distributed.

Growers found tubers of Sequoia to be very susceptible to late blight and common scab and thus confirmed results obtained in tests at the Potato Investigations Laboratory.

Essex, a late blight-resistant variety, matured very late at Hastings. Its yield was satisfactory but its tubers were too immature, skinned easily, shrunk and browned badly when dug 100 days after planting.

Red Pontiac is a high-yielding variety. However, there is very little demand for Hastings-grown, red-skinned potatoes and usually not over one percent of the acreage is planted to Red Pontiac.

Sebago has been the leading variety of potato grown at Hastings for the last 11 years. It has superior chipping and marketing qualities. The maximum yield obtained from Sebago grown in the best soils on well-managed farms in 1952 was 350 hundred-pound sacks per acre; in 1953 a yield of 467 sacks per acre was recorded for the variety in one field where the potatoes were planted thickly and heavily fertilized and growing conditions were especially favorable.

EFFECT OF CHANGES IN FARMING PRACTICES ON POTATO YIELDS

The average yield of potatoes grown on each acre at Hastings has increased 122 percent during the last 16 years, as is shown in Table 2. Spaulding Rose, the leading variety planted at Hastings for over a quarter century, became severely infected with ring rot (*Corynebacterium sepedonicum* (Spieck. and Kotth.) Skapt. and Burkh.) and virus diseases during the 1930-1937 period. It was abandoned as soon as it could be replaced with adapted varieties free of those diseases. By 1942 Spauding Rose had been dropped and the new varieties, Katahdin and Sebago, had taken its place. The superiority of Sebago over Katahdin was soon recognized, and by 1945 the former had replaced the latter. The average yield in the 1938-1945 period was 84 hundred-pound sacks per acre. The 33.3 percent increase in yield over that produced in the 1930-1937 period is attributed mostly to the shift to the higher-yielding Sebago. Replacement of mule-drawn implements with modern tractor-powered machinery for cultivating the crop, and improvements in the irrigation and drainage of potato fields also helped to increase yields.

Production of an average yield of 140 hundred-pound sacks of potatoes per acre during the 1946-1953 period is attributed to the planting of Sebago on 95 percent or more of the acreage, to better fertilization and culture of the crop and to more effective control of diseases and insects.

TABLE 2.—Comparison of Average Yields of Potatoes Grown on Farms in the Hastings Area, Florida, from 1930 to 1953.

Period	Years	Hundred-pound Sacks per Acre*	Percentage Increase in Yield Over First Period
1	1930-1937	63	—
2	1938-1945	84	33.3
3	1946-1953	140	122

* Average of the annual yields per acre reported by the U. S. Bureau of Agricultural Economics.

Rate of seeding generally increased in the 1946-1953 period from about 1,000 pounds to 1,500 pounds of seed per acre; in a few fields 1,800 to 2,000 pounds of seed per acre were used. The amount of fertilizer

applied per acre also was increased from about 2,000 pounds of a 5-7-5 mixture to 2,500 pounds of mixtures with formulas varying from 5-7-5 to 7-9-9. The cover crops, sesbania or hegari, were planted in most fields after the potatoes were dug and then turned under in the fall to maintain and improve fertility of the soil. Treatment of new land and old cultivated soils testing pH 5.0 or lower with enough lime to adjust their reactions to pH 5.3 to 5.5 and the application of fertilizers containing one to two units of nitrate nitrogen was adopted as a regular practice to correct for nutritional leaf-roll and improve yields (5).

Nabam spray was introduced for the control of late blight in 1946 and by 1953 almost all potato fields were sprayed with that fungicide. DDT also was used in almost all potato fields for control of insects.

CONCLUSIONS

Sebago has equalled or excelled 31 other potato varieties and 125 USDA seedling selections in yield and other characteristics in tests made at the Potato Investigations Laboratory during the last 16 years. Its tubers have superior market and chipping qualities demanded by the trade. It has been the leading commercial variety planted at Hastings during the last 11 years and is capable of producing 350 hundred-pound sacks or more of marketable tubers per acre when planted in good soil on the best managed farms during favorable growing seasons.

The average yield of potatoes grown in the Hastings area from 1930 to 1937 was 63 hundred-pound sacks per acre and increased to 140 sacks per acre during the 1946-1953 period. The increase in yield per acre during the last 16 years is due mostly to replacement of the Spaulding Rose, Katahdin and other low-yielding varieties with the high-yielding Sebago, and to changes in farming practices such as (1) use of cover crops to improve the productive power of the soil, (2) increasing the quantity of seed and fertilizer used per acre, (3) liming of acid soils to pH 5.3 to 5.5 and use of fertilizer containing one to two units of nitrate nitrogen for correction of nutritional leafroll, (4) improvements in drainage and irrigation, (5) more effective control of diseases and insects and (6) better cultivation of potato fields with tractor-powered machinery.

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BREEDING FLUE-CURED TOBACCO FOR ROOT-KNOT RESISTANCE AND DESIRABLE LEAF TYPE

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The objective of the flue-cured tobacco breeding program in Florida is to combine high yield, good leaf type, and good quality with root-knot nematode (*Meloidogyne species*) resistance. It is estimated that root-knot nematodes on the average reduce the yield of tobacco in Florida by 10 - 15%, and in many instances whole fields are destroyed. In addition, considerable sums of money are spent each season for soil fumigation to control root-knot.

All commercial varieties of tobacco are susceptible to root-knot nematodes. Thus far there is only one source of nematode resistance in *Nicotiana tabacum*, L., and this was introduced from Colombia, S. A. during the 1930's. This introduction has very narrow leaves and is not suitable for commercial production. Unfortunately, resistance appears to be closely associated with the narrow leaves. Tobacco breeders, both State and U.S.D.A. workers, have grown many hybrids derived from crossing this resistant line with susceptible varieties, but thus far no one has succeeded in isolating among the segregates a line which has both good resistance and wide leaves.

The close association of root-knot resistance and narrow leaf type may be because these characters are controlled by the same gene or genes. Such an association is called pleiotropism. If such is the case, the association cannot be broken. Alternatively, the association may be due to linkage of genes with infrequent crossing over. If the association between high nematode resistance and narrow leaf type is close linkage, the desirable changes should be possible.

Although the results obtained so far by breeding are disappointing, it may be possible, if only linkage is involved, to set up a breeding plan whereby the re-ordering of the intermingled genes can be brought about and the desirable combination of leaf type and high resistance obtained. That this may entail considerable effort can be pointed out by a simple example. If it is assumed that c-D are linked and C-d are linked, each with a 1% crossover, the desirable combination will be the homozygous CD genotype. This genotype will show up only once in 40,000 times in a segregating population resulting from a cross between the two genotypes assumed above. There is the additional difficulty of selecting that genotype from the population. If it is assumed that more than one pair of genes affect each character, the probability of selecting the desirable combination in one cycle of breeding becomes rather small.

Along with a discussion of his plan for recurrent selection for specific combining ability, Hull (1) in 1945 proposed for self-fertilized crops frequent interbreeding of selected lines when breeding for improvement in complexes of multigenic characters. In 1951, following Hull's outline,

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a recurrent selection breeding plan was initiated. The choice of this plan was based on the assumption that the association between narrow leaves and high resistance is linkage and not pleiotropism. This breeding program has not been in operation long enough to determine if any progress is being made.

In addition to the general breeding program, two experiments were initiated. The first was designed to test the hypothesis that the association is linkage instead of pleiotropism, and the second was designed to test the feasibility of using a first generation hybrid tobacco commercially.

FIRST EXPERIMENT

Experiment number 1 was designed to provide data that could be used to estimate genetic correlations between leaf width and root-knot nematode resistance and also to estimate genetic variances of these characters. If the association between the two characters is pleiotropic, the genetic correlation should be a minus 1.0. The estimates of genetic variances would allow prediction of expected progress in one cycle of selection.

The genotypic correlation between leaf width and roots galled was found to be .30. This positive correlation indicates that as leaf width increases, the percent of roots galled also increases. An increase in roots galled would indicate increased susceptibility and decreased resistance, which means that the correlation between high resistance and leaf width is negative. Although this result was expected, the fact that the correlation is .30 instead of 1.0 suggests rather strongly that the association between leaf width and high resistance is linkage and not pleiotropism. This low correlation increases confidence in the recurrent selection breeding plan now in use.

The phenotypic correlation between leaf width and roots galled was .13, and this smaller phenotypic correlation indicates that the infestation of nematodes is preventing the leaf width genotypes from expressing themselves completely. The phenotypic and genotypic correlations between leaf length and roots galled were found to be −.05, which shows the lack of association between these two characters except that there may be a depressing effect of the nematode infestation on leaf length expression. The genotypic correlation between leaf length and leaf width was .32, which points out that as leaf length or leaf width is increased by selection, there will also be an increase in the other associated character.

The magnitude of genotypic variability varied between each of the characters studied. For example, the coefficient of genetic variability for leaf length was 5.84%, for leaf width 3.67% and for roots galled 18.1%. The indicated potential improvement from selection, measured in percent of the mean, is considerably greater for roots galled than for the other characters. If it is assumed that the best progenies in terms of any one character will excel the mean by two or more standard deviations, it is indicated, for example, that an occasional progeny should be up to 36% superior in root-knot resistance, whereas a comparable figure for leaf length is only about 5%.

Another way of expressing genetic variability is by heritability estimates. By definition, heritability is the percent that the additive genetic variance is of the total phenotypic variance. The heritability estimate for leaf length was 5.84%, for leaf width 3.67% and for roots galled

29.12%. These estimates are indicative of the low genetic variability present in this population for leaf length and leaf width.

Even though the genetic variability for leaf length and leaf width is relatively small, considerable progress can be made by selecting in this population. For example, it can be shown that the formula for expected genetic advance is

$$\frac{K\ Vg^*}{Vc}$$

By substituting the appropriate values in the formula and assuming that 5% of the superior progenies were selected, the expected genetic advance in leaf length becomes .72 inches, or 4.6% of the mean of the population. The expected advance for leaf width is .63 inches or 7.25% of the population mean. The expected advance for roots galled is 1.68 or 50% of the population mean.

In addition to selection among progenies, selection among plants within progenies may also be considered. The additional progress to be anticipated from this intra-progeny selection can be approximated in terms of a formula analagous to that used in the case of inter-progeny selection. By substituting the appropriate values in the formula and selecting the top 5% of the plants in each plot of selected progenies, the additional progress from intra-progeny selection for leaf length, leaf width, and roots galled becomes 1.2%, 1.65%, and 9.1% respectively. The reason that intra-progeny selection is less effective than inter-progeny selection is in part that intra-progeny selection is based on single plant performance which is influenced considerably by environmental factors.

The predicted genetic advances reported here apply only to the specific population from which the data were collected. These estimates of genetic advances are the first of this nature to be reported for tobacco; they give some indication of the amount of genetic advance which might be expected in such populations.

SECOND EXPERIMENT

In the event of failure to isolate a homozygous gene combination, there remains the possibility of obtaining a desirable heterozygous gene combination for use in a first generation hybrid tobacco. F_1 plants from crosses between susceptible varieties and resistant lines have sufficient resistance for the average tobacco field condition in Florida. Unfortunately, the F_1's produce only about 80 to 90% as much tobacco as an adapted variety when grown on non-infested soil. In an attempt to find higher yielding combinations that could be used as parents of F_1's, and also to make a survey of the amount of hybrid vigor that existed in progenies which resulted from crosses of different varieties, a second experiment was conducted. This experiment consisted of seven varieties of tobacco and all possible F_1's between them grown in a replicated test. Yield, price per pound, plot value and height were determined on each entry.

*K = number of standard devitations by which the selected individuals are superior to the group from which they were selected. In theoretical populations k can be computed from a normal curve of error.
Vg = the additive genetic variance.
Vc = the mean phenotypic standard deviation.

All F_1's exhibited heterosis for all characters in that the F_1 means were greater than the means of the parents except for one variety for the character of price per pound. There was a considerable variation among the specific combinations in the amount of heterosis exhibited. Unfortunately, none of the F_1's yielded significantly more than Bottom Special, which was the superior variety in this test. Although in all probability no combination would be used in the production of a "hybrid" tobacco, some were superior enough to warrant consideration in a breeding program. Generally, the indications were, if a variety was a high yielding variety, its progeny were not nearly as likely to exhibit as much heterosis as a low yielding variety. A tentative explanation of this trend is that two low-producing varieties would be low-producing because of two or more different characteristics and in the F_1 would complement each other, while the higher producing varieties would not complement each other so much. Along with this goes the possibility that these flue-cured tobacco varieties probably have a narrow genetic background and the higher producing varieties are similar in genetic make-up.

Hull's (1) regression analysis was applied to these data. The means, the partial regression coefficients (bp), and the regression of the partial regression coefficients on the variety mean (b_2) were computed for yield, plot value, and height.

The bp is a relative measure of the heritability of the character in question in the particular tester group. The average bp, or heritability, was largest for height and smallest for yield. This indicates that yield, in this population, is influenced more by the environment than height.

With as much heterosis as was exhibited in this population, if the heterosis is due to dominance and following the assumptions of the analysis, the b_2 values should be negative. The b_2 values for yield and plot value were positive and with an assumption of no epistasis would indicate dominance for low yield. This is inconsistent with the amount of heterosis exhibited and leads one to assume that considerable epistatic gene action is being expressed, especially for yield which had a relatively large b_2 value. The trend of the bp values for plot value and height tend to be curvilinear which indicates that both dominance and epistatic gene action is being expressed for these two characters.

It should be pointed out that these data are representative of one small population and are not extensive enough to allow valid conclusions to be drawn from them. They do, however, lead one to conclude that hybrid tobacco is not economically feasible unless tobacco of a more diverse origin is available.

SUMMARY AND CONCLUSIONS

The selection of nematode resistant varieties of flue-cured tobacco has been hindered by a close association of high resistance and narrow leaves. A genetic correlation of .30 between leaf width and nematode resistance indicates that this association is linkage and not pleiotropic. Other genetic correlations show no association between leaf length and nematode resistance, but a positive correlation between leaf length and leaf width. Genetic variances estimated indicate that genetic advance can be made for increased resistance and increased leaf width using the recurrent

selection breeding program now in progress. A test involving seven tobacco varieties and all possible combinations between them indicates that the amount of heterosis for yield, plot value, and price per pound is not sufficient to be economical in a production program. Hull's regression analysis applied to the F_1 data indicates some dominant and/or epistatic gene action present.

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IMPROVEMENT OF CIGAR-WRAPPER TOBACCO BY BREEDING

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The most popular variety of cigar-wrapper (shade) tobacco in Florida at the present time, called Rg, was developed at North Florida Station. It possesses blackshank resistance and other good qualities which have made it the predominant variety for more than 15 years. A continuous program of selection is conducted to maintain and, if possible, to improve this variety.

In the meantime, a search has been made for a new variety having advantages over Rg and no serious disadvantages, such as susceptibility to some important disease. Commercial varieties and experimental lines have been received from various states and other countries for testing and selection under Florida shade conditions. Numerous crosses have been made between Rg and other tobacco varieties and Nicotiana species having desirable qualities such as resistance to root knot or Granville wilt. Rg is susceptible to both of these diseases.

An experimental line received in 1947 from E. E. Clayton yielded by 7 years' selection a new variety which has been released under the name of Dixie Shade.[1] The new variety has blackshank resistance equal to that of Rg, less susceptibility to certain leaf spot diseases, and some resistance to root knot. Agronomic advantages include slightly greater number and width of leaves, higher yield potential, and better colors. The fire-holding capacity of Dixie Shade tested slightly lower than that of Rg. The new variety will be grown on a considerable acreage of shade in 1954.

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SYMPOSIUM: SOIL AND TISSUE TESTING

OBJECTIVES OF SOIL AND TISSUE ANALYSIS

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Soil and plant analysis serve two purposes in agricultural production. They provide research data to establish programs of fertilization for various crops and soils, or they may be used for examination of a grower's soils or crops for individual adjustment of his fertilization practices. It is the purpose of this discussion to segregate the various factors involved so that they may be more clearly understood in their proper perspective.

The value of soil testing often is confused with research analysis and the educational opportunity provided. The research and educational aspects have an obvious place in any program, but the objectives of service testing need clarification for Florida conditions.

The improved lands of Florida may be grouped as follows (5):

Horticultural crops	925,000 acres
General crop land	1,100,000 acres
Crop land replanted to pasture	932,000 acres
Total	2,957,000 acres

A fairly complete soil testing service, including analysis for elements which generally must be applied annually, such as potassium, has been estimated as requiring one sample from each ten acres of improved land. The cost of such an analysis is about one dollar per sample, or an annual cost of $300,000 for the three million acres of improved land.

Soil analyses such as those for pH and phosphorus usually need not be made annually. The cost for such a limited service would be considerably less. The problem of evaluating soil testing in Florida, then, is not one of a decision for or against the service as a whole, but rather one of degree of service in terms of the types of analyses justified for different areas.

In 1941 the writer emphasized that soil pH was an essential measure of soil condition for Florida, but that acceptance of other determinations was largely dependent on the ability of soils specialists to devise methods of extraction of nutrients which would correlate with plant growth over a range of soils (8). This was more recently stated by Bray (2) as his first requirement for a successful soil test as follows:

"1. The extracting solution and the procedure used should extract the *total amount (or a proportionate part)* of the available form or forms of a nutrient from soils with *variable* properties."

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THE CHANGING PICTURE

The use of fertilizers, especially outside of the southeastern states, has increased markedly during the past fifteen years. This also marks the period during which soil testing has had its greatest increase in popular acceptance. Soil testing has helped to bring to attention many conditions of low fertility but, conversely, the real value of soil analysis has yet to be determined, because recommendations for sustained or increased fertilization have been almost universal. The real evaluation of soil testing will come when the use of fertilizers has increased to a point at which economic necessity demands recommendations for reduced applications of fertilizer as frequently as increases. In Florida, certain types of production already approach the maximum to be expected from increased fertilization, while other types, notably field crops and pastures, are underfertilized.

When recommendation is made for substandard fertilization on high-fixed-cost crops, only for the purpose of economy in fertilizer used, it must be handled with great caution because the cost of fertilizer saved usually is only a small part of the cost of production. Economic return does not rise gradually to a maximum as with low value crops, but very abruptly as maximum production is approached.

A great change has come about in methods of analysis, primarily as a result of the development of the flame photometer. Methods for turbidimetric determination of potash and the various rapid methods for magnesium and calcium are obsolete for those laboratories which can afford the new instruments and have personnel qualified to keep them in adjustment. The accuracy of certain of the old rapid laboratory methods under routine use was less than the literature generally would lead one to believe, mainly because interferences from unknown variables in soil extracts were improperly evaluated in the supporting data (9). Such methods have a tendency to average out true variation between samples and thus lead to a false concept of uniformity. This is especially true of rapid methods for the determination of nitrate nitrogen in plants and soils. They may give a maximum test before the real critical value is approached, as shown in Figure 1.

THE NATURE OF SOIL RESERVES

The soil test is intended to determine the amount of reserve nutrients in the soil, the associated factors such as pH that influence their availability, and the presence of toxic amounts of reserve nutrients or other constituents. Available reserves in the soil must be divided into two types, especially for Florida conditions. The first consists of reserves of those elements which may exist or be built up to such an extent that one or more crops may be produced without supplementing this reserve. The build-up of phosphorus in old citrus groves is a good example. A Lakeland fine sand at Gainesville has shown a differential accumulation of 700 pounds of P_2O_5 in the surface soil as compared to the subsoil (11).

The second type of reserves consists of those elements which the soil will not accumulate in a quantity large enough to carry crops for a long period of time but must be applied every year or to every crop. Potash and nitrogen are good examples of elements to which a response usually is obtained on the mineral soils of Florida.

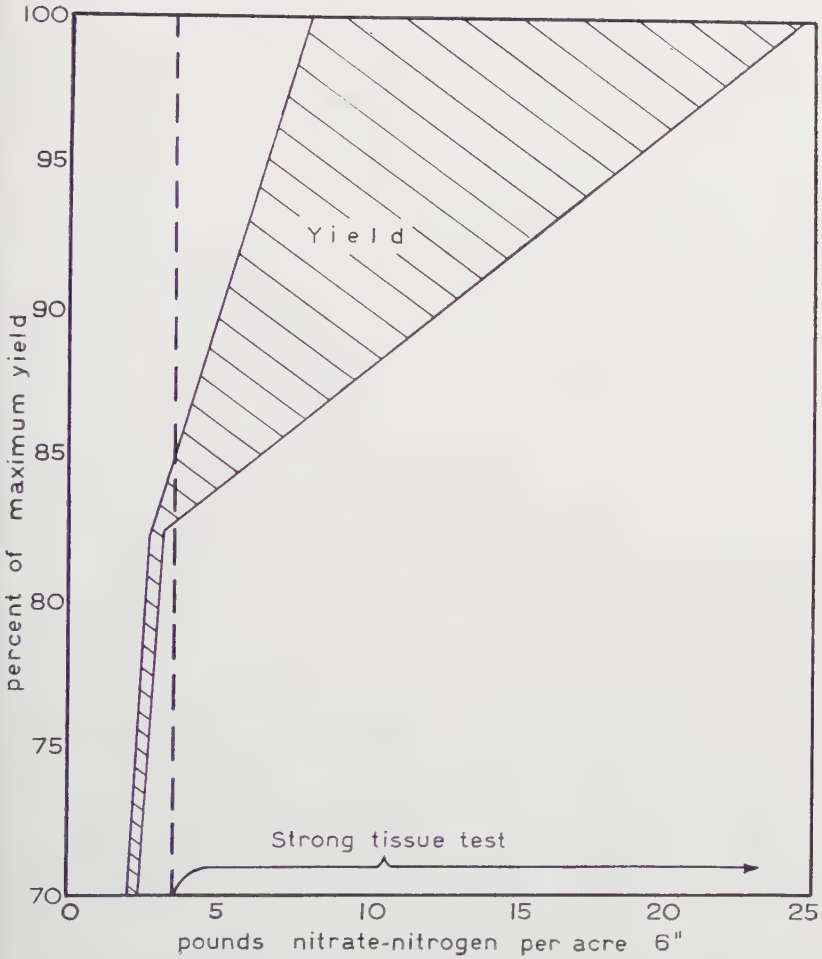

Figure 1.—The relationship of nitrate nitrogen content of the soil and of the plant to yield. The soil was analyzed by Harper's method and the tissue by spot test on the petiole in the field using diphenylamine. The yield spread is largely due to variable nitrogen sources used and is indicated by the soil test (10).

The ability of a soil to build large reserves is very important from the soil test standpoint. With large reserves it is possible to set a large factor of safety for an element in interpreting the soil test. It is perfectly safe to recommend that no phosphorus be used if analysis shows that a supply sufficient for several years exists. On the other hand, the reserve of potash in a Florida soil usually is insufficient to grow a crop and must be supplemented by fertilizer potash. Advantage of the partial reserve can be taken only by reducing the potash recommendation to less than standard, and the factor of safety will of necessity be relatively small as compared to that of a highly retentive soil where the reserves of potash may be efficiently built up to a several years' supply. Thus potash ap-

pears to be closely related to nitrogen and other low reserve elements in Florida and must be treated in somewhat the same manner.

Potash exhibits other peculiarities in Florida soils not common to the well buffered mineral soils. Only a fraction of the exchangeable potash is removed by a given crop from a well buffered soil because only that portion of the soil near the roots is extracted. With poorly buffered sands the mobility of potash is much greater, especially when strong anions such as the nitrates, chlorides, and sulfates are present, making it possible for the plant to deplete the soil more uniformly and completely. A further enhancing factor in this depletion is the inability of such soils to hold potash back against the absorbing power of the root. When a heavy application of potash is made to a corn belt prairie soil, it stores only a part of the potash in the readily available form while the rest moves farther into the soil mineral complexes from which it tends to return to the available form at a relatively slow rate as the readily available potash is depleted.

In Florida soils the plant may luxury feed on potash applied as fertilizer to the extent that often the reserve is gone before the season is over (1, 3). A well buffered soil would tend to force the plant to use potash at a rate more in keeping with its needs. This means that for Florida soils potash must be applied frequently and in limited amounts, a condition more difficult to evaluate by a service soil test than where large reserves may be built.

SERVICE SOIL AND PLANT TESTING vs. A FERTILITY PROGRAM

It is necessary to differentiate between a *fertility program* in which all or part of the fertilization practice is covered by a standard set of recommendations for a given soil type and crop; and a *soil testing service* in which individual fields are sampled and special recommendations made. The soil and plant analysis approach must be divided into three sections.

(a) Soil Tests for pH and Possible Full Reserves of Certain Elements. This type of service is the most common because it can be carried out with relative ease by centralized organizations. Tests for toxicity could be accommodated here.

(b) Detailed Annual Service for Partial Reserves. A major problem is introduced in Florida because potash falls into this type of service rather than under (a). This service to be successful requires an intimate knowledge of the soils and crops of an area, a condition much more difficult to fulfill than under (a). It also requires great detail of calibration and sampling for soil variation.

(c) Special Service for Close Seasonal Control. This type of service would include plant and soil analysis for seasonal modification of side or top dressing practices on annual crops. It appears to be practical only if set up as part of a commercial crop production unit such as a large grower or cooperative or similar closely integrated service.

Both the fertility program and service testing have certain strong points. The program has the uniformity and simplicity of complete control over an area, using research to adjust the program as general reserves develop under a given practice. The strong points in favor of a testing service rest mainly on the determinations of more extended significance, i.e., pH and full reserves, and on determining toxicities.

The weakness of solely a program approach is the lack of control of pH or interfering excesses, and inefficient use of large soil reserves, while the major weaknesses of the complete testing service are the possibility of underfertilization through errors in sampling or interpretation, and the time lag between sample collection and application of results. The difficulty of obtaining representative samples from growers is a major weakness but one which must be accepted in any practical service. To invalidate collection by growers would markedly limit the practicability of a service. Obviously the strongest system would include the best of each approach.

THE ACCURACY OF THE SOIL TESTING SERVICE

The value of a soil testing service depends on accurate analyses within the complete range of extraneous constituents in soil extracts to be encountered: and on the field calibration of the method for the soils and crops in question. Calibration of a method for a small area of uniform soil is relatively simple. The fallacy of accepting statistical significance for precise tests on small soil areas non-representative of the variability to which the data are to be applied, is a major weakness to date.

The real problem is one of recognizing soil variation, and determining if detailed calibration to take it into account leaves a method with any practical value. If soil variation is so great that a large factor of safety is required for the method, then the test has no practical value over a standard recommendation.

Any given critical value usually is not applicable over a wide range of soil variation. The extraction of 50 pounds of potash per acre from a light soil does not carry the same significance as does removal of the same amount from a heavy soil. The problem is not as great for those elements which build large reserves because the factor of safety can be increased to help offset this variable.

The writer has always considered the sampling unit as the minimum area which a grower feels must be fertilized uniformly for practical reasons. Soil variation seldom fits a pattern that allows for its practical delineation in fertilization, therefore uniform fertilization usually applies to the field unit set up by the grower.

The next question is how much of the variation within the unit should be recognized in fertilizing. For practical reasons it appears that no greater precision than recognition of the fertility of the lowest one-third of the sampling unit need be made. It is assumed that if a major variation in fertility exists, it can be seen as a recognizable soil variation or will be known from past experience by the grower. The minimum number of samples necessary to obtain this precision would be three, taken to represent thirds of the field by obvious or known soil variation. The recommendation could then be modified within reason by the variation in the analyses. The collection of three samples from a given unit has the further advantage of permitting recognition of a completely abnormal sample resulting from plugging a spot where fertilizer was spilled or similar abnormality existed.[1]

[1] This problem is given an excellent detailed discussion in a paper by Pritchett et al. to follow.

This approach is complicated by a factor brought out by Figure 2, which represents a 2½ acre area of about average uniformity for much of the Hastings area. The soil moisture equivalent percentage varies from an average of about 4.1 in the poorest one-third to 6.3 in the best one-third, with productivities of about 260 and 450 bushels of potatoes, respectively. Obviously, less fertilizer is needed for the lower production. Further complicating factors are the residual levels of available phosphorus and potash. Both build up higher in the better soils in the area, as would be expected. Values taken from similar soils in the area indicate that the analyses would show about twice the residual available potash and phosphorus in the high one-third as would be present in the low one-third under typical uniform heavy fertilization.

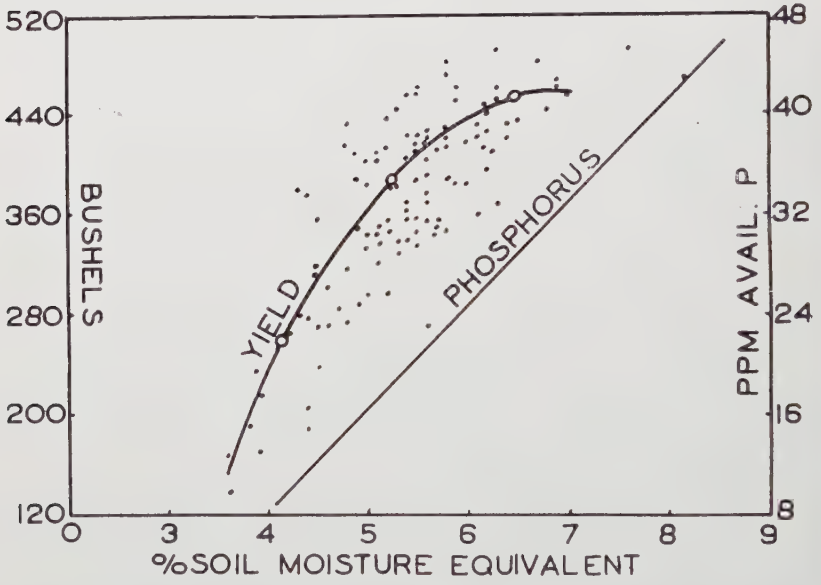

Figure 2. Relation of percentage soil moisture equivalent to yield of Irish potatoes. Experimental points are individual plot yields distributed over a total area of 2½ acres, varying from Leon fine sand to Bladen loamy fine sand. (The curve is drawn parobolic, $x = 7.17 - \sqrt{0113(456-y)}$, to the three median points shown). The available phosphorus line indicates the residual to be expected as determined by associated tests on these soils (15).

If the relationship shown in Figure 2 could be depended upon for all Florida conditions it appears that an average soil test value for a field would be the most practical. This probably will hold quite well for the sandy peninsular soils, but it has been shown that the relationship of yield to retentiveness of soil may be completely reversed where heavy soils are encountered, because of adverse moisture relationships on certain of the heavier soils (13).

Each soil sample should be made up of several plugs distributed over the area it is to represent. Eight to ten plugs should make an adequate sample (7), because simple calculation will show that an eleventh plug

would have to be more than double the average for the other ten in order to increase the average value by over 10 percent.

The key to the problem in Florida lies in determining a factor of safety sufficient to cover soil variation and then to ascertain if this is sufficient improvement over a standard recommendation to justify its use. To proceed without this information is giving blind recommendations that must approach a standard program if any factor of safety is to exist. An unrecognized factor that has functioned to give a false sense of security in some instances is the reluctance of growers to follow any recommendations for less than common practice except in cases of suspected toxicity.

Sampling of soils after fertilization, with the intention of adjusting side dressing practices, presents a somewhat different problem. Figure 1 shows the expected yield spread for cabbage in the Hastings area using nitrate nitrogen as a criterion of nitrogen status. This spread from about 8 to 24 pounds of nitrate nitrogen for maximum yield is the result of different nitrogen sources. A rapidly growing crop was found to utilize nitrate nitrogen from non-nitrate sources almost as fast as formed in some instances, allowing little excess to accumulate in the soil; while those fertilized primarily with nitrate sources showed large excesses for considerable periods after fertilization, but often with no greater effect on yields (13).

Sampling following band placement gives very erratic data as shown by Table 1, but even here three samples of ten plugs each would give a

TABLE 1.—Variation in Nitrate Nitrogen in Soil Following Replicated Drill Application of Fertilizer to Cabbage (13).*

1500 Lb. 10-7-5 Applied 11/8/44				2000 Lb. 10-7-5 Applied 11/8/44			
Plot No.	Percent Moisture Equivalent	PPM Nitrate Nitrogen 1/29/45	PPM Nitrate Nitrogen 2/28/45	Plot No.	Percent Moisture Equivalent	PPM Nitrate Nitrogen 1/29/45	PPM Nitrate Nitrogen 2/28/45
3	5	70	21	6	5	31	44
5	5	33	15	61	5	61	17
16	5	34	32	7	6	32	17
88	5	6	3	22	6	7	3
19	6	47	8	77	6	47	38
41	6	16	17	31	7	39	43
42	6	23	4	32	7	43	12
49	6	37	10	38	7	56	17
66	6	26	17	39	7	64	43
30	7	39	8	75	7	49	34
25	9	58	45	13	8	28	53
67	9	39	39	47	8	56	28
74	9	11	11	60	8	25	18
84	9	35	19	80	8	19	38
45	10	29	33	81	8	47	58
56	11	42	24	46	9	50	28
	Average	34	19		Average	41	31

* All nitrogen was applied in the nitrate form on 11/8/44. Each of the respective 16 plots was treated alike. They were 225 sq. ft. in area and part of an 88 plot randomized block experiment approximately one-half acre in total area. Plots were sampled by compositing 7 cores from the vicinity of the fertilizer band in each plot.

fair representation of the *average* condition of the area. In fact, a large number of plugs may tend to mask a variation that it might be desirable to know. The factor for the test, in general, would have to be determined by examination of data such as shown in Table 1. Even then it would apply only where nitrate nitrogen was the dominant or sole source of nitrogen for the crop. It is evident that sampling according to soil variation would not give an adequate estimate, because it cannot be assumed that low values represent soil of lower productivity. In this instance the reverse probably would be true for nitrogen and potash because the most vigorous plants would deplete the supply the most rapidly.

The error inherent in post fertilization sampling is between individual plugs of a sample and is averaged out by the composite. It is an extremely difficult factor to evaluate in a practical way and suggests that a side dressing program is to be preferred except where close personal attention can be given.

OBJECTIVES FOR FLORIDA CONDITIONS

Figure 3 is an attempt to present the concepts already discussed in a simple chart that may help to separate the more controversial points from those upon which quite universal agreement may be expected for Florida conditions.

The objectives of soil and plant analysis may be separated into the five groups listed across the top of the chart. Soil and plant analysis is an invaluable tool of *research* in connection with overall improvement of crop production practices, and needs no further discussion.

A *fertility survey* consists of any practice which contributes data on the fertility status of soil types or groups of soils. This may be made by a direct systematic collection of samples for analysis, or may be the indirect result of accumulation of data on the random samples submitted by growers under a testing service. This is a valuable contribution, but not a justification in itself because a better and more reliable coverage could be made by a systematic survey similar to that of Sims and Volk (6) on vegetable crops and their related soils.

Crop production service refers to the analysis of soils and plants from the fields of growers in the business of crop production, as differentiated from *dooryard service* which applies to the problems of a householder's lawn, garden and ornamentals. The latter is treated separately because it involves culture that follows no set pattern and may involve abnormalities not encountered under large scale commercial production.

Public relations could as well have been called educational opportunity. It is one of the most valuable phases of any testing service because it establishes a close contact between the grower and the agricultural specialist and allows for greater distribution of up-to-date crop production information even though the actual laboratory tests may or may not be of additional value to a grower.

Soil and plant analysis as a crop production service must be divided into *preplanting soil analysis* intended to supply information on the amount of fertilizer needed at or before planting, and *post planting soil and plant analysis* which is intended to determine the need for side or top dressing to supplement fertility still remaining from that applied at planting.

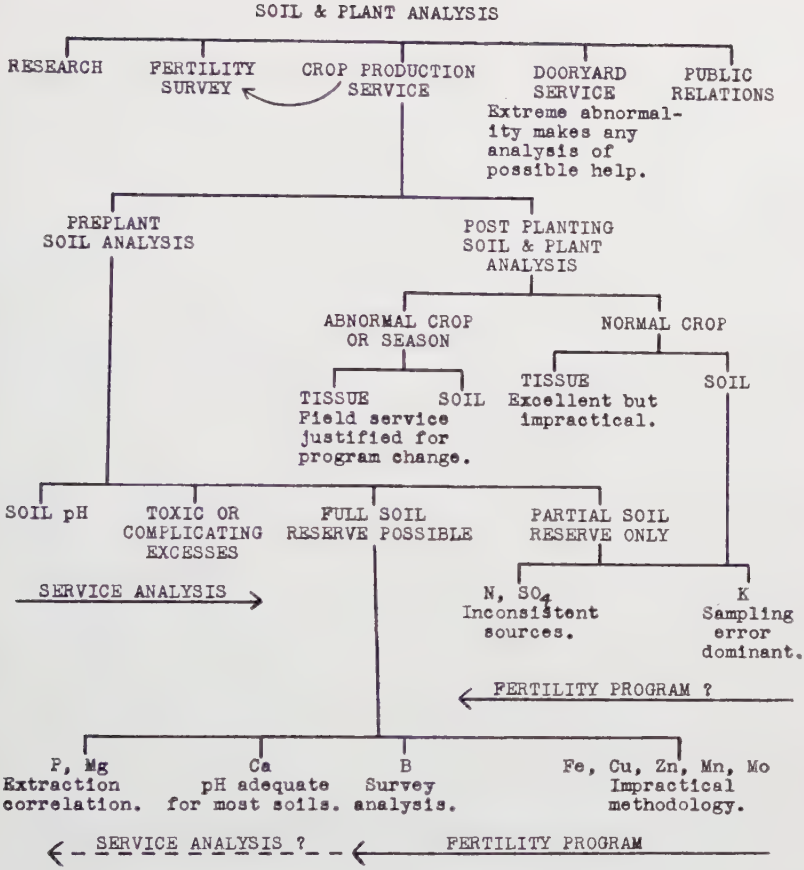

Figure 3. Objectives of soil and plant analysis for Florida conditions.

The latter or post planting service should be differentiated between *normal* and *abnormal* crops. If the crop is abnormal there is the definite possibility that some factor may be involved that is of interest from the research angle and could be used for an adjustment of the fertilizer program. But if the crop is as expected and shows only normal need for side dressing, the use of soil or plant tests, while valuable if properly done, may not be justified because of their exacting nature and the large sampling error following band applications.

Returning to consideration of the preplant soil analysis, it may be discussed most simply by dividing into *soil pH. toxic or interfering excesses, full soil reserves,* and *partial soil reserves.* There is little question of the value and justification in the case of soil pH and toxicity.

Partial soil reserves covers those elements which are not retained by most Florida soils in amounts sufficient to grow the crop in question but must have fertilizer supplements. This problem already has been discussed at length and the present outlook is that the requirement of many

crops is so high as to place these elements predominantly under a fertility program. The possibility of finding value in the tests for potash still exists for some areas, notably the organic soils and certain of the most retentive mineral soils (4), especially if under crops requiring relatively light fertilization. The survey by Sims and Volk (6) showed exchangeable potassium values of over 200 pounds per acre at the time of harvest for many of the organic soils of the state. It is possible that this represents a very temporary reserve that could produce a follow-up crop of low requirements, but the nature of this reserve may be such that its association with high anion concentration would make it very subject to leaching loss if much time elapsed between the soil test and the planting of the next crop.

The response to sulfur probably would be widespread if it had not been added in superphosphate over the years. The effect of elimination of sulfur from lysimeter treatments made in 1944 was so drastic that almost complete transplanting of a turnip crop was necessary to get a stand of vigorous plants. Sulfur additions produced a one-third increase in final yield (12).

For those elements which may exist or be built into full reserves in Florida soils there are certain qualifying factors such as methodology or correlation that make a further grouping desirable. Certain of the minor elements—iron, copper, zinc, manganese, and molybdenum—do not lend themselves to service soil analysis because of the impractical nature of the chemical methodology involved. They, along with boron, should be approached on a survey basis. Boron is classed by itself because, while native boron reserves may be adequate in most instances, it still appears impractical to rebuild reserves where they are low. Borax and similar soluble forms leach readily so that their use as a supplement becomes similar to the problem with nitrogen and potash (16).

Of the three remaining elements it usually is sufficient to interpret calcium supply from soil pH. A pH between 5.5 and 6.0 carries sufficient calcium for crops favoring this range except possibly for shallow rooted crops on the very lightest soils. While calcium supply is suspected of being inadequate in certain of these soils even at favorable pH values, no conclusive experimental data are available and probably could not be obtained wherever superphosphate is widely used in the fertilizer because of the calcium it carries.[2] If this material is eliminated it is very possible that a response to calcium will be obtained even at the higher pH values on certain of the lower east coast soils.

On the other hand, the efficiency of potash on the well drained upland soils under perennial crops capable of tapping the deep subsoil indicates that the same might be true for calcium and magnesium even at relatively low apparent levels in the surface soil. Table 2 shows the efficiency of a deep profile of slightly acid sandy soil in retarding the movement of potash. Much of the potash, calcium and magnesium in perennial crops not harvested for their vegetation returns to the ground to be held in the plant cycle and used repeatedly. This efficiency of deep profiles of light sands is difficult to evaluate by analysis of surface soil samples.

[2] A depressing effect of SO_4^{--} and PO_4^{---} on calcium determination by the flame photometer was brought to attention by N. Gammon, Jr., Florida Agricultural Experiment Station, as a result of work on heavily fertilized Florida soils.

TABLE 2.—Concentration of Various Ions in Leachate from a 4-Foot Profile of Lakeland Fine Sand in 1/2000 A. Lysimeters to which 253 Pounds of $MgSO_4$, 183 Pounds of $NaNO_3$ and 157 Pounds of KCl per Acre Were Placed in Double Bands Similar to Field Crop Usage but Kept Fallow (14).

Date	Leachate, Inches Cumulative*	Average Milliequivalents per Liter of Leachate Between Preceding and Given Dates						
		Ca	Mg	Na	K	NO_3 – N	SO_4 – S	Cl
February 7	.5	.92	.32	—	.010	.93	—	.08
February 19	1.4	1.00	.18	.06	.009	1.28	.04	.14
March 1	2.8	2.13	.53	.24	.007	2.59	.03	.85
March 1	3.8	3.04	.86	.73	.013	3.32	.11	1.70
March 8	5 0	3.12	.96	1.22	.008	2.98	.45	2.00
March 16	6.3	2.17	.33	1.15	.010	2.50	.58	1.39
March 19	7.4	1.24	.34	.61	.010	1.43	1.00	.77
March 24	8.7	1.16	.33	.53	.018	.99	1 03	.47
April 11	9.7	1.01	.47	.33	.027	.70	1.20	.29
May 29	11.3	.76	.36	.27	.023	.27	1.05	.13
June 3	12.2	.69	.31	.21	.025	.31	.92	.09
June 20	13.1	.79	.35	.17	.036	.45	.85	.10
June 25	14.7	.82	.35	.13	.037	.57	.70	.08
July 3	16.4	.83	.35	.16	.043	.71	.61	.08
Lbs. per acre leached		103	19	36	3	70	37	75
Lbs. per acre applied		none	51	49	83	30	68	74

* 2.23 inches of leachate passed between treatment on Jan. 18 and collection of first sample.

Note that all bases except potash responded to anion crests.

The movement of calcium, magnesium and potash from recently improved acid flatwoods mineral soils is an entirely different problem. Here the test of the surface soil is misleading in the opposite direction. The limed surface with its relatively high pH is retentive of potassium and possibly magnesium applied as fertilizer salts, while the strongly acid subsoils have little retentive power for these or the salts of calcium (11). A gradual pH increase will take place due to continued passage of neutral salts through the acid subsoils, but calcium movement in the form of bicarbonate from applied lime will proceed very slowly, probably not ahead of a front of a pH of 6.0 (11).

A major problem in the use of soil tests for calcium, magnesium and phosphorus is the correlation with crop response. An enhancing factor with phosphorus will be the simultaneous reduction of sulfur and soluble calcium if the use of superphosphate is reduced. Extensive tests to determine crop response to sulfur and calcium on various soils are needed in order to take advantage of available phosphorus reserves.

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SOIL AND TISSUE TESTING PROGRAMS IN OTHER SOUTHERN STATES

J. Fielding Reed*

Today every state in the South offers some type of soil testing service. Most of these have developed since the middle 1930's. Prior to that time, soil testing services were offered in the Middle West and Northeastern states, and some states in those areas had rather detailed programs that involved handling of rather large numbers of samples. However, the program did not really move into the South to any extent until the late 1930's. For the first few years that these laboratories were operated in some Southern states they were a rather strongly debated and controversial issue. In those days many states questioned the value of soil testing. Since then, soil testing has progressed to the point where it is now generally accepted as a very useful tool for diagnosing general fertility levels of the soil, and for assisting in fertilizer recommendations.

It is now recognized that while soil testing is not an infallible means of predicting the exact fertilizer needs of a crop, it is an excellent method of estimating such properties as the acidity status and the level of certain plant food nutrients in the soil. These properties are certainly helpful, then, in arriving at the fertilizer and lime requirements of the soil. Used in such a manner, soil testing has now assumed its place in all of our Southern States. The programs are handled in different manners in the various states. It is the purpose of this paper to review the manner of approach to the soil testing problem used in the various stations. In addition, consideration will be given to the possibilities and present use of tissue testing in the South.

Agencies Responsible for Soil Testing

There is a rather marked difference among the Southern States in the assignment of soil testing programs to various agencies:

(1) In some states, the experiment station is responsible for the entire program. Generally these states acknowledge the fact that soil testing is a service to farmers, but feel that at present the experiment station is the best agency to handle its interpretation. States in which the experiment stations' personnel handle the program almost exclusively include Louisiana, South Carolina, Georgia, Alabama, Florida, and to a large extent Arkansas.

(2) Another approach is to place the service end of soil testing in the hands of the Extension Division. This is the practice in some states, particularly as far as making recommendations, interpreting the tests, and promoting their use are concerned. Southern States in which the Extension Division has a large part in the soil testing program include Mississippi, Texas, Tennessee, Oklahoma, and Kentucky. Actually the program is handled in quite a different manner in each of these states, but in all cases the Extension Service has a prominent part.

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(3) In one state, North Carolina, the soil testing service is operated as a part of the State Department of Agriculture. Since soil testing is considered a service feature and the State Department of Agriculture is responsible for most service and control work, it was placed in this Department. Actually, the program is manned by research type personnel along with some extension type personnel. There is a very close relationship between the soil testing personnel in the State Department of Agriculture and the Experiment Stations, and the Director of the Soil Testing Program is a joint employee of both divisions. This is a unique program and has worked quite satisfactorily in North Carolina, but such an approach might be entirely out of the question in another state.

Source of Funds

A problem facing all soil testing laboratories is that of supporting it financially. Again we run into quite a variation in the South:

(1) Some soil testing services receive no support directly and depend entirely on being a part of the general experiment station program.

(2) Others receive some experiment station support and finance the rest of their program by charging a fee for testing soils.

(3) Another practice involves financing primarily through the extension service. Where this practice is followed, soil testing often receives some support from experiment station funds to support the research phase of the work.

(4) Some soil testing programs are supported by special taxes. For example in North Carolina and in Arkansas the state inspection tax on fertilizer was increased by a small amount in order to finance the soil testing program. This type of financing through special taxes has usually resulted in a rather liberal amount of money for soil testing, and part of these funds can be devoted to both the research phase of soil testing and to field work designed to standardize or calibrate soil testing.

Thus, we again see the picture of variability among the stations in the matter of financial support.

The figures for the support of soil testing laboratories vary from nothing to approximately $60,000.00 per year. Stations which charge a fee for soil testing include Tennessee, Kentucky, Oklahoma, Alabama, and Texas. In most cases the fee is $1.00 or less and will not cover the cost of running the test. However, it is the feeling that setting up a small charge for testing will develop a program in which the person sending in a sample is more likely to use the information and will send in only such samples as he is really interested in. This psychology is one in which there is no general agreement.

System of Handling Soil Samples

Radically different approaches exist among the soil testing programs in the way in which the system is set up.

(1) Some states handle all of the testing through one central laboratory. The feeling in these states is that one well equipped laboratory

that is staffed by well trained personnel can handle the program more efficiently. States that subscribe to this system include North Carolina, South Carolina, Alabama, Tennessee, and Texas.

(2) Another system involves a central laboratory at the state university or state experiment station with additional branch laboratories at substations. Where this set-up is used, the entire program is directed from the main station, in some cases, while in others, the main station handles its particular program, but the operations at the substations are separate units and each sets up its own program. States in which both central and branch laboratories exist include Arkansas, Louisiana, and Florida. In Arkansas and Louisiana all of the laboratories are under the direction of the main station.

(3) Some states have a main central laboratory and in addition have a few county laboratories set up. This is true in Mississippi where approximately five county laboratories are in operation in certain counties where interest has been high and where the farmers and agricultural workers in that county wanted a service of their own. Such laboratories were set up under the direction of the main station, and are subject to frequent checking by the man in charge at the main station.

(4) Some states operate almost entirely through county laboratories. This work is patterned after the system first set up in Illinois. In Oklahoma there are approximately sixty-four county laboratories, and in Kentucky approximately eighty-three.

(5) In the soil testing program in Georgia, laboratories are set up at the various branch stations as well as at the University, and in addition, Georgia has been using four to five mobile laboratories. These are paneled trucks equipped as laboratories for testing soils, which are operated out of either the main station or one of the branch stations. Each mobile unit has a territory to cover, and a schedule is set up for the appearance of different mobile units at various county seats and vocational schools. The method in use as well as the interpretation is determined generally by the branch station from which the unit operates.

Comparison of Soil Testing Systems

The question that is frequently asked about these various approaches to the soil testing problem is: "Which is the most effective, the most economical, and the best service?" This is a difficult question to answer because the answer depends so largely on conditions within a particular station. In Florida for example where each of the experiment stations is a strong unit with well trained personnel, and where the soil and cropping conditions are so different in the various parts of the state, the problem is quite different from that presented in a state such as South Carolina. It is certainly not within the scope of this paper to decide what is the best system for any particular state. However, a few comments will be made about experiences that the various stations have had with their particular systems. Where county laboratories are in use, there is the great advantage of a personal type of service. Frequently the farmer is dealing with someone who knows his individual problems and can give

him a personal touch in the recommendations. On the other hand, there is the problem of keeping the personnel trained and up to date in the county laboratories and also the problem of keeping the personnel interested in soil testing problems. A county agent or assistant agent has a great many calls upon his time. Frequently he is not in a position to know when solutions or reagents go bad, and there is always the problem of maintaining precision in this type of laboratory. There are many excellent possibilities to the county laboratory approach, but it should be recognized that this approach requires frequent checking from someone in charge on a state level and refresher courses for the personnel who are making the determinations and interpretations. In connection with the mobile units, they have been a very attractive promotional feature. If the mobile unit is taken out on a farm and a group of farmers gather around and see the test run and discuss the recommendations, there is a definite psychological effect. However, on the other hand, if the visits of the mobile unit are rather infrequent in a particular county or locality, it is actually faster to mail the samples into the central laboratory rather than to hold them pending the arrival of the mobile unit.

If funds are not a factor in setting up a soil testing program, one of the best systems would appear to be that involving a central laboratory with one individual responsible for the entire program, but with laboratories also located in the branch stations and operated under the supervision of a person who devotes his entire time to the soil testing program in that area. That person would have time to follow up work in his area and should be a sort of service agronomist for the section in which he operates. He could include tissue testing in his follow-up program and in time would become thoroughly familiar with the farmers and the agriculture of the area. At any rate all of these various systems have worked quite effectively in the states where they are operated, and certainly any state must develop a system which is best suited to its own agricultural needs. In all of this discussion the place of the commercial laboratory has not been mentioned at all. Certainly many of these over the United States render an excellent service, but this paper has been restricted to state operated laboratories, since the others are covered by another speaker.

Tissue Testing

Tissue testing has proved itself as a diagnostic tool, and is one which could and should be used to much better advantage in the South. This method of diagnosis involves either a rapid test of plant tissue in the field or a collection of plant tissue in the field which is brought into the laboratory for more detailed analysis. Often this latter method is called plant analysis to distinguish it from the rapid tissue testing in the field.

There is no conflict in soil testing and tissue testing. One can very nicely supplement the other and both have somewhat different objectives. For example, it is not possible to determine lime needs by means of tissue testing, and on the other hand, it is frequently much better to determine nitrogen needs by tissue testing rather than by soil testing. Rapid tissue testing in the field has been used successfully in the midwestern states, but has never assumed its proper place in the South. Many agencies are sold on the possibilities of this tool, but the fact is that few of them have put it into actual operation in the field. One reason,

of course, is that the person using it must be quite well trained in its use as well as in its interpretation. Because of this, it has not been too well used among the county agent group in the South. This tool is one that offers tremendous possibilities for extension specialists, branch station personnel, and other extension workers who will acquaint themselves with its use. In time, it undoubtedly will take its place along with soil testing as one of our most helpful diagnostic procedures.

In conclusion, it should be emphasized that wherever soil and tissue testing have been used in the South, they have been met with an enthusiastic reception from the farmers and agricultural workers. While the approach is different among the various states, they seem to fit their respective needs quite well and are serving agriculture in all cases.

CURRENT FACILITIES FOR SOIL TESTING IN FLORIDA ON A SERVICE BASIS

A. Commercial Laboratories

C. C. Thornton*

In opening this brief discussion on our current facilities for soil testing in our Tampa laboratory, I would like to say that we have attempted to follow essentially the recommendations of the State and Federal Experiment Stations as to analytical procedures. However, we have made several slight but important changes in these procedures in order to aid us in giving our customers a much faster service. The State Experiment Station at Lake Alfred has for several years been using, with one or two slight modifications, the analytical methods as published by Michael Peech and Leah English of the Cornell University Agricultural Experiment Station staff. These analytical methods were published in the March 1944 issue of Soil Science. It is these exchangeable methods that we are now using after having made our slight changes and after having adopted the modifications as suggested by the Lake Alfred staff. The U.S.D.A. Experiment Station in Orlando has also been using these analytical procedures in their soil research work. However, in the last two years or so they have changed from exchangeable base determinations to acid-soluble totals on several elements and we have since incorporated these "totals" determinations into our scheme of soil analysis. We will describe our methods in detail at a later point in this discussion.

The equipment in our soil department is all of the conventional manufactured type with one or two exceptions. The revolving shaker for soil extractions that we are now using was made for us locally. It consists of a barrel type frame on a horizontal shaft and has four extraction flask trays that are detachable. Each of these four trays will accommodate nine extraction flasks so that we may extract up to thirty-six soil samples at one time. This shaker is operated by an electric motor. In addition to this piece of equipment, we have various test tube trays, water baths, cooling baths, etc., all designed to handle thirty-six samples to correspond to the shaker. Our factory manufactured equipment consists of 2 Beckman pH meters (model M and model N), a Beckman model B Spectrophotometer, a Cenco colorimeter, a Klett-Summerson colorimeter, a titration lamp, an electric muffle, an International centrifuge, and an air conditioned room. Our soil department has its own separate supply of all necessary pyrex glassware including pipettes, burettes, squibb tubes, test tubes, centrifuge tubes, funnels, volumetric flasks, Erlenmeyer flasks, graduated cylinders, etc.

During the last year and a half, we have been classifying all soil samples into two groups, namely, citrus and non-citrus. This was done primarily because of the wide variety of soil types received by us for analysis, and because we had decided to run acid-soluble totals for phosphorus, manganese, iron, and copper on citrus soils. Furthermore, this

* Thornton and Company, Tampa.

grouping led to a more orderly and efficient processing of all samples through the laboratory with a saving in time and expense. With the above points in mind, this is a good place in which to tabulate the different determinations that we run under each group.

	Soil Types	
Element	*Citrus*	*Non-Citrus*
pH	pH meter	pH meter
Ca	Exchangeable	Exchangeable
Mg	Exchangeable	Exchangeable
Mn	Total	Exchangeable
P	Total	Exchangeable
K	Exchangeable	Exchangeable
Fe	Total	Total
Cu	Total	Total
N	Total	Total
S	Total	Total
Cl	Total	Total
Al	Total or Exchangeable	Exchangeable
Bx	Exchangeable	Exchangeable
B	Total	Total

When a soil sample is delivered to our laboratory for analysis, it is received in our main office and immediately assigned a laboratory number. This number serves from this point on as a means of identification to all of our laboratory personnel and is included on our certificate of analysis. As a further aid to our customers, we furnish printed slips with spaces provided for the identification history of each sample, the type of soil, and for checking the various determinations desired. These slips are filled out by the customer and attached to the corresponding soil samples. On the reverse side of these slips, there are spaces so that the result of each determination may be entered. In this way, we have all information on any specific soil together and at the same time have a permanent record for our files since these individual slips are filed after the results have been reported. As soon as all necessary paper work has been completed in the receiving office, the samples are removed to the preparation room where they are screened and prepared for analysis. From the preparation room the samples are next taken to the soil laboratory proper where they are checked and grouped into lots of thirty-six samples or less. After these groupings are complete, we make out a single chart for each group showing the laboratory number, customers name, types of soil, and all determinations to be made. This single chart aids our chemists in following the flow of work as each set progresses through the many operations required and materially reduces any possible chance of errors.

After thirty-six samples or less have been properly grouped and recorded on our master chart, we are then ready to weigh out portions for all tests involved. pH is always run the same way for both citrus and non-citrus and is merely a pH meter reading after equal portions of soil and water have stood for one hour with several agitations during this period.

For the extraction of the sample for determinations of exchangeable bases, we weigh 10 gms. of soil into a 125 ml. Erlenmeyer flask, add ¼ to ½ teaspoonful of charcoal, and 50 ml. of sodium acetate extracting solution (pH 4.8). These flasks are then placed on the revolving shaker

and rotated for 30 minutes. At the end of this time the solutions are filtered through a Whatman No. 1 - 15 cm. filter paper into a 125 ml. Erlenmeyer flask. These filtered extracts are now ready for aliquoting into test tubes for the various desired exchangeable base determinations.

As mentioned previously, we are at present running acid-soluble totals for phosphorus, iron, manganese, and copper on all citrus soils. In obtaining these totals, we have to digest ten grams of the soil with sulfuric and nitric acids until all organic matter is destroyed. This acid extract is then digested with water until all salts are in solution, cooled, made to volume, mixed, centifuged, and is then ready for aliquoting.

Calcium is a very important element in any soil analysis and is one of the most frequently requested determinations that we have in our work on soils. It is the first element listed in our table so we will begin the brief discussion of our methods with its determination. We run calcium on an aliquot from the sodium acetate extraction on both citrus and non-citrus soils and of course this means that we always report exchangeable calcium. The actual test is a turbidimetric method involving a relationship between the calcium present in the soil extract and the soap contained in the test reagent. This turbidity in the unknown sample is then compared visually with a set of standard calcium solutions carried through the same procedure. One precaution on this test is the fact that the samples should be kept below 28° C. and this is where our air conditioned room is a very convenient asset.

Magnesium is another important element in soil chemistry and is one that we always determine as exchangeable on both citrus and non-citrus soils. Our method for this element is a colorimetric one and is based on a color relationship between the magnesium in the soil extract and titan yellow. As in the case of calcium, this color is compared visually with a series of standards prepared in the same manner as the unknowns.

We are at present running manganese by two different methods, namely, exchangeable and acid-soluble total, depending on the group into which the soil sample is placed. On non-citrus soils, we determine exchangeable manganese on an aliquot from the sodium acetate extract by developing the manganese color with bismuthate and comparing visually with a series of standards. In the case of citrus soils, this element is determined on an aliquot from the acid-soluble total solution and is run by a colorimetric method employing periodate to develop the color. This color is read on the Klett-Summerson colorimeter using a green filter.

Phosphorus is also determined in two different ways. On non-citrus soils, an aliquot from the sodium acetate extract is treated with stannous oxalate and the color compared visually with a series of standards. This of course gives us exchangeable phosphorus. For total phosphorus on citrus soils, the phosphorus color is developed in an aliquot of the acid-soluble total solution by the use of amino-naphtholsulfonic acid. This color is read on the Klett-Summerson colorimeter using a red filter.

Potassium is always on an exchangeable basis on both groups of soils and is therefore determined from the sodium acetate extract. Here we use a turbidimetric cobaltinitrite test and visually compare the final turbidity with a series of standards. These solutions are also kept below 28° C. during the duration of the test.

Iron is always determined as acid-soluble iron on both groups of soil. We employ two methods to obtain this total iron and our choice of which one to use is based on the other elements requested on that specific soil analysis. If iron is the only total to be determined, we ignite the sample at a low temperature, extract with hydrochloric acid, reduce with stannous chloride, and titrate with potassium dichromate. When other totals are to be run, iron is obtained by developing a color with 0-phenanthroline hydrochloride on an aliquot from the acid-soluble total solution. This color is read on the Klett-Summerson colorimeter using a green filter.

We determine copper on an aliquot from the acid-soluble total solution on both groups of soils. This aliquot is treated with carbamate solution, extracted with iso-amyl acetate, and the color read on the Klett-Summerson colorimeter using a blue filter.

Nitrogen, sulfates, and chlorides are determined as totals on both the citrus and non-citrus soils. Nitrogen is always run by the Kjeldahl procedure. We determine sulfates by igniting a portion of the soil, extracting with hydrochloric acid, filtering, and precipitating the sulfates with barium chloride. In the case of chlorides, a sample is expracted with water, filtered, and titrated with standard silver nitrate solution.

We have very infrequent calls for aluminum analysis on soils any more either on citrus or non-citrus soils. We are set up to run this element by two methods depending on the requirements and desires of the customer. Acid-soluble aluminum is determined by igniting a sample of soil, extracting with hydrochloric acid, filtering, separating from iron with sodium hydroxide, precipitating with ammonium hydroxide, igniting and weighing as alumninum oxide. In the case of exchangeable aluminum, we treat an aliquot of the sodium acetate extract with aluminon (ammonium salt of aurintricarboxylic acid) and compare visually with a series of standards.

Base exchange is always determined in the usual way. This consists of extracting the soil with neutral ammonium acetate, washing with alcohol and salt solution, and subsequent distillation by the Kjeldahl procedure.

Requests for boron analysis on soils have greatly increased during the last two years or more. We determine boron as an acid-soluble total on both citrus and non-citrus soil. During the last five years, we have investigated at least three or four colorimetric methods for the determination of this element and have finally decided that the carminic acid procedure gives us the most reliable results. This method involves ignition of the soil sample, extraction with hydrochloric acid, filtering, developing color with carminic acid, and reading these colors on the Beckman model B Spectrophotometer.

Most of our soil work is conducted for fertilizer companies and large grower organizations who have in their employ the necessary trained personnel to interpret the results of our analysis. However, we are available for interpretation of soil analysis results and recommendations based thereon upon request where production or soil management problems exist. We maintain no regular field supervision beyond the occurrence and duration of the above mentioned problems.

CURRENT FACILITIES FOR SOIL TESTING IN FLORIDA ON A SERVICE BASIS

B. Fertilizer Companies

V. E. Woods and R. K. Voorhees*

It might be in order to give a brief resumé of how our company got into soil testing on a service basis. In 1932 the company considered it advisable to determine the soil reaction (pH) from certain fertilizer materials, mixtures, and soil conditioners in bearing citrus groves on an average acid sandy soil type. Accordingly, certain experiments were initiated in the Davenport area and conducted over a four year period. Following this period and with certain laboratory facilities at hand the company was in position to run limited soil analyses at customers' request. From this as a starting point in 1936, we have gradually increased our laboratory facilities in an attempt to meet the ever increasing demand for soil tests. However, in soil testing on a service basis, we have necessarily limited our tests to pH and certain major elements on which there is a more general knowledge of crop response or a more liberal interpretation of the tests. Whenever additional tests are considered advisable we call on help from the Commercial Laboratories or the Experiment Stations.

In general, we do not solicit samples, since our laboratory is usually swamped with samples sent in direct by certain customers but mostly by or through our fieldmen. The bulk of our soil sampling is done by our fieldmen as a part of the routine service to our customers. Moreover, the majority of the soil tests are followed up by them insofar as possible, and the interpretation and/or recommendations are made to the best of their ability or through the assistance of the Experiment Stations or Extension Service.

As indicated above our soil testing on a service basis began with tests of citrus soil samples, and which still outnumber those pertaining to other crops. For these reasons and because of the location of our laboratory, we have probably been prone to follow the procedure of certain chemical analyses by the Citrus Experiment Station more closely than other agencies. In regard to pH tests, we changed from the Quinhydrone apparatus to the Beckman Glass Electrode pH Meter in 1935 and have continued with this type since then. We use the battery type meter because of the fluctuation of the electric current at our laboratory. Although, we run soil tests on certain elements we feel that the pH test is often of more value in determining soil fertility than any other test within the realm of our facilities.

In regard to tests for calcium, magnesium, and potassium, we employed the J. B. Hester method between 1936 and 1952 as modified and recommended to us by Michael Peech to fit our facilities. In 1952 we changed to the Peech-English method of "Rapid Microchemical Soil Tests".

* Wilson & Toomer Fertilizer Co., Davenport and Wilson & Toomer Fertilizer Co., Jacksonville.

as modified by I. W. Wander to use the 3 ml. cell on the Fisher Electrophotometer. We are aware that the pH 4.8 sodium-actate extracting solution is not the best for certain soil types, but since our soil samples from these types are at a minimum we are using this method for the most part.

For several years our soil tests have been limited primarily to citrus, vegetables, and certain field crops. More recently, however, with the influx of pasture improvement there has been considerable interest in the testing of pasture soils. Thus, in addition to testing for the above elements in pasture soils, we had several customer requests on tests for phosphorus and potassium. Although we were testing for potassium by the above method we had to seek a method for phosphorus tests. Also, since the majority of early requests on pasture tests were on muck soils, we solicited the help of the Belle Glade Experiment Station for a reliable phosphorus method, and we are now employing the water soluble method as recommended by W. T. Forsee. The majority of our phosphorus and potassium tests to date have been on pasture soils, because we feel there is a more liberal interpretation of the tests as correlated with the response of certain pasture crops.

In conclusion, this chemical soil testing on a service basis has definite limitations because of its economics, lack of reliable interpretation, and practicable application of certain tests to certain crops. Moreover, we are cognizant of the inaccuracy of certain kit methods as employed by certain agencies, and that false information can be misleading and often hazardous. Thus in attempting to run and interpret soil tests, we believe there is a dire need for the standardization of methods by all soil testing agencies as far as practicable. Also, a more intensive educational program by the Experiment Stations, Extension Service, and other agencies on reliable methods of soil sampling and testing as correlated with crop response.

CURRENT FACILITIES FOR SOIL TESTING IN FLORIDA ON A SERVICE BASIS

C. Suggested Improvements

O. C. Bryan*

My experience with farmers, citrus growers, cattlemen, and Soil Science Foundation leads me to feel that soil testing as an answer to the soil problems of Florida is confusing to many people. Much time and effort are wasted in running soil tests alone. The practical interpreter must include a number of factors other than the soil analysis. To overlook soil structure, soil depth, stage of the crop growth, season, moisture, cover crops and antagonistic effects of one nutrient with another, means incomplete interpretation, and often confusion. Furthermore, the absence of properly calibrated crop response data seriously limits the best of interpretation. The soil test is only a part of the information needed before interpretations can be made.

The primary purpose of soil testing and analysis is to furnish dependable data regarding the available soil nutrients and the possible nutrient antagonism inside the soil. Without an inside "chemical eye", it is impossible for the interpreter to avoid errors. Nutrient antagonism is in evidence in many soils. This is particularly true in intensive farming areas on sandy lands. Therefore, the analysis should reveal not only the actual quantities of nutrients available, but the probable inter-actions with each other. Records show that high amounts of potash interfere with utilization of magnesium. Furthermore, high amounts of iron interfere with utilization of phosphates, and vice versa. Soil reaction (pH) often materially hinders the utilization of nutrients revealed in soil testing.

The chemical approach to soil analysis is an old subject and can be done by many technicians. The reagents employed consist of dilute acids and different salts designed to duplicate plant root effects. The over-all records indicate that most any extracting reagent will enable the technical worker to secure reliable data when calibrated crop responses are available. The absence of calibrated crop response data seriously handicaps the use of the test, regardless of the efficiency and refinement of the best reagents and extracting methods.

Unless the crop capacity and needs are known, the use of soil analysis may be a liability. For example, the fertilizer needs of a peanut crop are far different from those of potatoes and corn, though the soil tests may reveal identical information. Furthermore, a citrus grove of 100 box capacity per acre would need far less fertilizer than one with 500 box capacity. Soil moisture and temperature have a marked influence on the utilization of fertilizer. Moisture penetrates through sands far more readily than through clays and loams. Cool weather slows down the activity of the plant as well as the transformation of insoluble nutrients over to soluble forms. Soil tests will give the extent of these factors, but the interpreter must know far more than the results of soil tests.

* Technical Director, Soil Science Foundation, Lakeland, Fla.

The weakest link in the soil testing program in Florida is the absence of calibrated crop response data for the major soils and crops. This places undue responsibility on the interpreters, which frequently leads to confusion. Florida has five major soil groups, namely, (1) the organic soils consisting primarily of peats and mucks, ranging from acid to alkaline conditions, and from a few inches to several feet in depth. They occur largely in the Everglades, but scattered deposits are found over the state. (2) The marls and highly calcareous soils are located near the coast. (3) Most of the loams and clay loams occur in north and west Florida. (4) Sands used for intensive agriculture are found in most every county, and (5) deep sands predominate in the peninsula. The organic soils and marls are usually poorly drained, but all of the other groups vary from overflow lands to uplands. Some of the organic soils are underlain with acid sands while others have marls, shells and acid clays underneath. Many gradation and transition stages occur in local areas.

Because of the inherent nature of the major soil groups, it would be unsound to expect equal performance of a given fertilizer. It would also be unsound to expect equal plant nutrients to have optimum efficiency on them. The variations within any one group are sufficient to create a wide range of fertilizer efficiency. What is high in one soil may not be high for another. The wide range of nutrients in the sands is illustrated in Table 1. Similar variations exist in each group of soils.

TABLE 1.—Variations in Available Plant Nutrients in Some Typical Grove Sands.

(Data Expressed in Pounds per Acre)

Soil No.	pH	Calcium	Magnesium	Nitrogen	Phos. Acid	Potash	Manganese	Iron	Copper	Zinc
A	5.1	656	84	11	20	65	12	2	60	6
B	5.7	1,800	180	95	210	105	11	13	10	8
C	6.2	380	35	25	110	120	4	15	1	1
D	5.8	1,000	85	15	35	60	2	4	3	10
E	4.8	950	75	10	125	185	3	18	.5	.5

This is an age of streamlined agriculture, when correlated information is the best assurance for success. The time is ripe for Florida to make her thinking count and put soil science to work. To overlook cold facts will not help.

Records indicate that experimental information demonstrating the critically *low*, *high* and *optimum* amounts of the needed fertilizer nutrients for the major crops on the important soil groups is limited. This means that the farmer and the interpreter face serious difficulty in finding sound starting points and establishing safety zones in fertilizer usage. Furthermore, little attention has been given to nutrient antagonism and balanced fertilizers geared to soil and plant needs. This is very important for sand. These are basic problems deserving systematic study under normal and accepted tillage and crop operations, with a reasonable

variation of soil moisture and soil reaction. Because of the complexity of soil and nutrition problems, and the time necessary to secure dependable information, it is doubtful that commercial, private and farm organizations are able to secure the needed correlated data and guides for sound interpretation and use of soil analysis, the absence of which seriously limit the progress of soil testing.

After all is said and done regarding soil analysis, crop performance records under normal growing conditions take precedence over all other data. If properly calibrated crop response data are available for the major soils, reliable information can be secured for the individual local soils as well as the transitional and off-type soils so common in the state. Without the established guiding points for the major soil groups and crops, the interpreter is seriously handicapped. The magnitude of local and individual soil variations is too great to permit generalized fertilizer recommendations based on soil tests. There is no way of escaping the individual and specific soil problems which need "on the job" attention. The leading farm people are beginning to view soil testing on the same basis as that of tractor repairs and even fertilizer applications.

Leading farmers and growers, as well as practical operators are far more interested in dependable and reliable data than they are in masses of uncalibrated data which are often meaningless. It is true that miscellaneous information is valuable and helpful for statistical studies, but it is rather doubtful that such information, at best, will furnish the needed data for a sound scientific program.

Once the basic calibrated crop response data are available for dependable interpretation, farm people will handle their local soil testing and relieve the public of much worry and trouble. This has been demonstrated by the establishment of several laboratories in Illinois and other states by farmers themselves. The urgency for basic information motivated a group of citrus growers in Florida, twelve years ago, to acquire a grove primarily to secure basic information as guides in fertilizer usage. The project has paid off.

If the members of Soil Science Foundation have realized a profit in their venture without correlated crop response data to start with, it would be reasonable to assume that the Foundation, as well as other farmers and growers would profit even more so, by having dependable guides upon which sound fertilizer practices could be safely projected. With this at hand, soil testing would take care of itself. Farm people will use a science, gamble with it, once they understand its application.

A rational appraisal of the soil testing program in Florida indicates that the public agencies, such as the experiment stations and universities, can render a most valuable service to the industry and the future progress of the state, by expediting their effort to provide correlated crop response data to the different fertilizer nutrients on the major soil types. This is a long time program, but it is basically sound; and without such data, the best of trained and experienced workers cannot avoid error and confusion. Such information will provide practical methods of calibrating any standard extracting reagent for soil analysis and testing, and permit a needed flexibility for local soil problems. The relative cost of securing this type of information in other states is not very great, yet pays good dividends. In my opinion this information takes precedence over all other data so far as soil analysis and testing is concerned.

CURRENT FACILITIES FOR SOIL TESTING IN FLORIDA ON A SERVICE BASIS

D. State Supported Laboratories

F. B. Smith*

The Florida Agricultural Experiment Station was established in 1888. The publications and reports since that time emphasize the fact that the work of the Experiment Station has been directed toward solving the problems of the Florida farmer. The report of the Chemist (now the Department of Soils) for 1901 (3) stated: "A *number* of analyses have been made and a *great many* letters of inquiry have been answered." The list of materials analyzed includes three soil samples. The reports through the years are characterized by similar statements. The major effort of the department has been directed along research projects and the publications have dealt with research results. Nevertheless, the service phase has not been neglected. The Annual Report for 1953 (9) will show that the Department of Soils tested 5,077 samples of soil in 18,557 determinations as a service to farmers.

The Branch Stations also have been active in service to farmers in their areas. Ruprecht (7) in a report from the Celery Investigations Laboratory (now the Central Florida Station) stated, "A *considerable* number of soil samples were tested for pH and *numerous* samples of water were tested for salt content." Forsee (2) reported approximately 1,900 service samples were analyzed at the Everglades Station during 1952. A survey[1] of current facilities for soil testing in five Branch Stations was made in December, 1953. The results of the questionnaire show that three of the five stations make soil tests as a service for residents of their respective areas.

QUESTIONNAIRE ON CURRENT FACILITIES FOR SOIL TESTING IN FLORIDA STATE-SUPPORTED LABORATORIES

1. Do you make soil tests for residents in your area as a service?

Central Florida Station	Yes
Citrus Station	No
Everglades Station	Yes
Sub-Tropical Station	Yes
Gulf Coast Station	No

2. How many samples, on an average, do you test a year or season?

Central Florida Station	2,000	
Citrus Station	.....	
Everglades Station	3,800	(Approximately, last year)
Sub-Tropical Station	250	
Gulf Coast Station	.....	

* Microbiologist, Agricultural Experiment Station, Gainesville.

Florida Agricultural Experiment Station Journal Series, No. 263.

[1] The cooperation of Dr. R. W. Ruprecht, Dr. I. W. Wander, Dr. C. T. Ozaki, Dr. J. L. Malcolm, and Dr. E. L. Spencer in completing the questionnaire is gratefully acknowledged.

3. Do you make fertilizer recommendations based on the results of soil tests?

Central Florida Station	In some cases
Citrus Station	No
Everglades Station	Yes, where sufficient experimental work has justified such procedures
Sub-Tropical Station	No
Gulf Coast Station	Yes, where correlated with research results

4. Do you accept pre-fertilization samples for anaylsis or do you limit your work to post-planting samples for diagnosing difficulties?

Central Florida Station	Both
Citrus Station	No
Everglades Station	Pre-fertilization samples are accepted
Sub-Tropical Station	(Yes). However, except for soluble salt, we have no soil troubles which can be diagnosed by soil testing that can't be corrected with a standard recommendation or careful analysis of the procedure following and the history of the field
Gulf Coast Station	For the most part our samples are limited to obtaining evidence to support field observations in diagnosing physiological disorders

5. If you accept pre-fertilization samples, what tests are made?

Central Florida Station	pH and water-soluble solids
Citrus Station	.....
Everglades Station	(a) pH, P and K on previously cultivated organic soils (b) pH on virgin organic soils (c) pH, Ca, Mg, and P on sands
Sub-Tropical Station	Chlorides, nitrates, phosphorus and potassium (on some samples)
Gulf Coast Station	...

6. What extractant do you use?

Central Florida Station	Hellige-Truog Kit
Citrus Station	Normal ammonium acetate, sodium acetate buffered at pH 4.8, water, mineral acids of various strengths, salt solutions, etc.
Everglades Station	Acetic acid, 0 5 N, for bases. Distilled water for phosphorus.
Sub-Tropical Station	Water extracts, usually 1:5, soil:water ratio
Gulf Coast Station	A weak sodium acetate solution except for phosphorus where water is used

7. What procedures are used?

Central Florida Station	Quinhydrone electrode for pH; Solu-Bridge for soluble salts; Hellige Kit for Ca, Mg and K
Citrus Station	Flame photometer, spectrograph and others
Everglades Station	Flame photometer for bases; stannous chloride reduction for P (colorimetric); Glass electrode for pH
Sub-Tropical Station	Titration or conductivity for chlorides; phe-

	noldisulfonic acid or brucine test for nitrates; phosphorus, stannous chloride reduction (colorimetric); flame photometer for K
Gulf Coast Station	...

8. Do you test for minor elements? Or any unusual conditions?

Central Florida Station	(a) Not usually; (b) Yes
Citrus Station	(a) Yes; (b) ...
Everglades Station	(a) Iron and aluminum on request; (b) Soluble salts
Sub-Tropical Station	(a) No; (b) ...
Gulf Coast Station	Only to support field observations in diagnosing physiological disorders

RESEARCH PROJECTS IN SOIL TESTING

Six research projects dealing with soil testing have been reported in the Florida Agricultural Experiment Stations Annual Reports since 1937, as follows:

1. Department of Soils—State Project 306.
   "A Study of the So-Called Quick Methods for Determining Soil Fertility."
   Initiated in 1937, concluded June 30, 1944.

2. Department of Soils—Purnell Project 256.
   "Development and Evaluation of Chemical and Physical Methods of Analysis in Agricultural Research."
   Initiated 1938, revised 1942.

3. Department of Soils—State Project 393.
   "Significance of Levels of Readily Soluble Major Nutrient Elements Removed by Various Extracting Procedures from Florida Soils Under Various Cropping Practices."
   Initiated 1943, concluded 1946.

4. Everglades Station—State Project 88.
   "Soils Investigations." First reported testing soils under this project in 1939. Testing soils and research on soil and tissue testing are still reported (1953) under this project.

5. Gulf Coast Station—State Project 448.
   "Rapid Soil Tests for Determining Soil Fertility in Vegetable Crop Production."
   Initiated 1945, terminated 1952.

6. Department of Soils—State Project 446.
   "Testing Soils and Limestone."
   Initiated July 1, 1945, still operative. This is the only project specifically designated to test soil samples sent in by farmers on a "Service" basis.

SUMMARY OF SERVICE AND RESEARCH UNDER STATE PROJECT 446

A press bulletin (8) was published in 1945 which explains the Soil Testing Service of the Department of Soils and discusses the value and limitations of a soil chemical analysis. Directions are given in the bulletin for taking soil samples. One laboratory in the Department was designated "Soil Testing Laboratory." All service samples come to the

DEPARTMENT OF SOILS

SAMPLE RECORD WORK SHEET

Name ..... Date .....

Address ..... Accession No. .....

Sample No.	O.M.	Texture	pH	Relative Amount of Available:									Chloride	Conductivity
				Ca	Mg	P	K	NO_3	NH_3	Mn	Fe	Cu		

REMARKS:

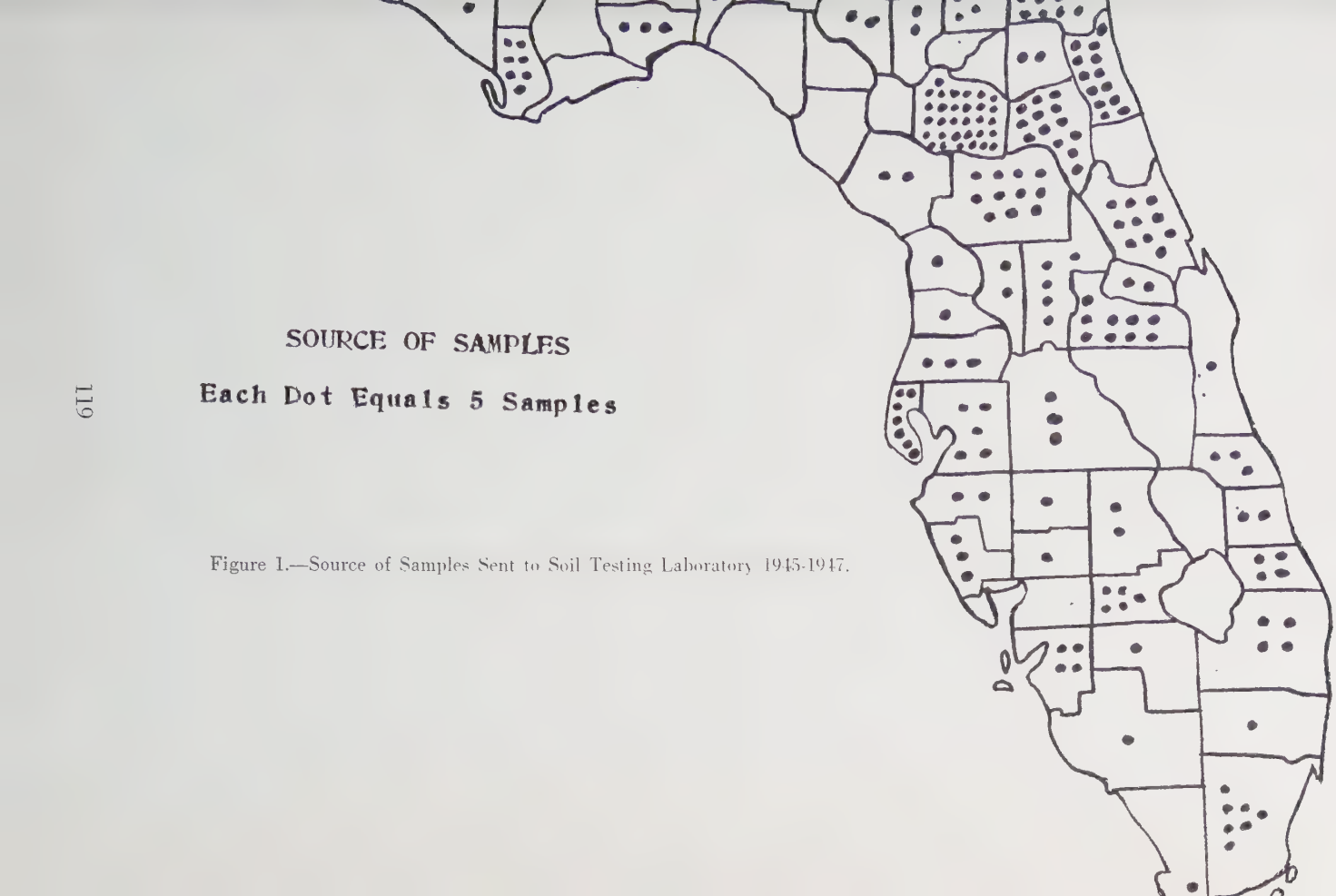

Figure 1.—Source of Samples Sent to Soil Testing Laboratory 1945-1947.

office where they are recorded and a "Sample Record Work Sheet" is attached. The sample is then sent to the Laboratory where a Laboratory Assistant makes the tests and returns the completed sheet to the project leader, who reports[2] on the analyses and makes recommendations. The work sheet and reply are filed for further study.

Certain tests are made as a routine on all samples. These tests include approximate organic matter, texture, pH, available calcium, available magnesium, phosphate, potash and nitrate. Organic matter and texture are determined qualitatively by comparing with known standards. The procedure for determining pH by the glass electrode as outlined by Carrigan (1) is followed. The procedures outlined by Morgan (4) were followed for determining available calcium, magnesium, phosphorus, potash and nitrate, in the samples described in this report. Results of research and observations on different soils led to certain changes in methods of analysis now being followed.

The reports of tests made show that 1,133 samples were sent to the laboratory from July 1, 1945 to June 30, 1947. The records show that 209 of these samples were sent in by county agents. The crop to be grown on these soils was designated on 414 of the reports. Of these, 140 were from the home garden, 140 were from general farms and pastures, and 134 from what might be regarded as commercial plantings of vegetable crops and fruits.

The number reporting physiological disorders was less than 2 percent of the total. Figure 1 shows that samples were sent in from 50 counties, with the largest number of samples coming from Alachua, Duval, St. Johns, Putnam, Marion, Volusia and Orange Counties.

Figure 2 shows the number of samples in the different textural grades. The data show that 62 percent of all mineral soils were fine sand; 20 percent, fine sandy loam; 8 percent, loamy fine sand; 7 percent, sand; and 3 percent, sandy clay loam.

The distribution of samples at different pH is shown in Figure 3. Sixteen percent of the samples were below pH 5.0, 40 percent were in the range pH 5.0 to 6.0, and 16 percent were in the range pH 7.0 or above. The median range appears to be about pH 5.5 to 6.0. However, the majority of the soils were strongly to moderately acid in reaction.

Figure 4 shows that most of the soils tested were deficient in the major nutrient elements.

Observations on soil test results from greenhouse and field experiments from 1947 to 1950 (11) indicated that Morgan's universal extractant was fairly satisfactory for phosphorus on acid, sandy soils. But it did not give good correlation with crop response on other soils, particularly some of the calcareous and high phosphorus-fixing soils. Studies were made using distilled water, carbon dioxide-saturated water, sodium acetate-acetic acid buffered at pH 4.8 (Morgan's) and 0.002 N sulfuric acid buffered at pH 3.0 on soils of widely differing chemical properties. The results obtained indicate a greater difference in the amount of phosphorus extracted from different soil types than between a given extractant for a given soil. For example, there was no large apparent difference

[2] Some reports, such as those on citrus, are sent to the Extension Citriculturist for reply, or to others in the Station or Extension Service where special information is required.

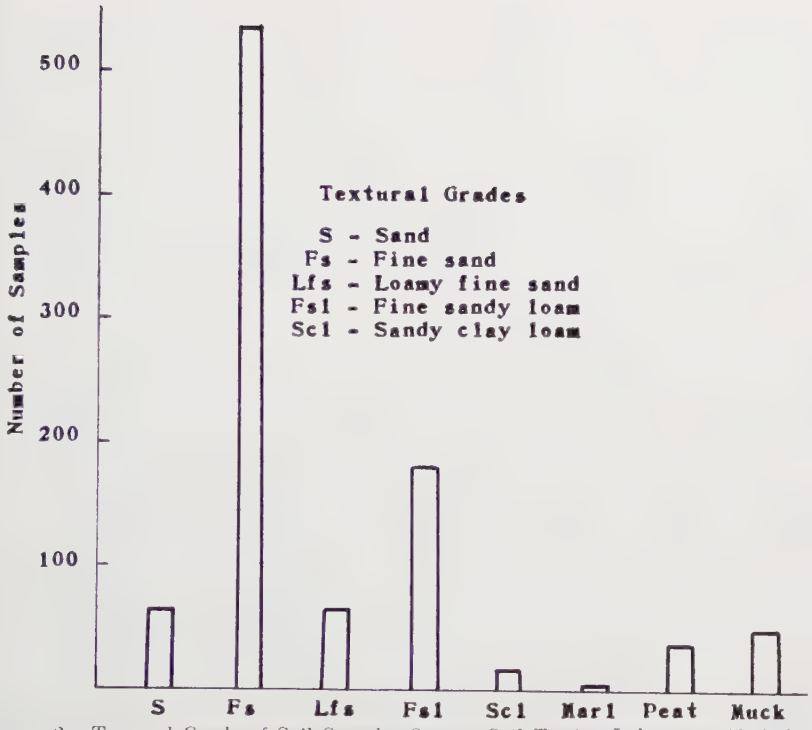

Figure 2.—Textural Grade of Soil Samples Sent to Soil Testing Laboratory 1945-1947.

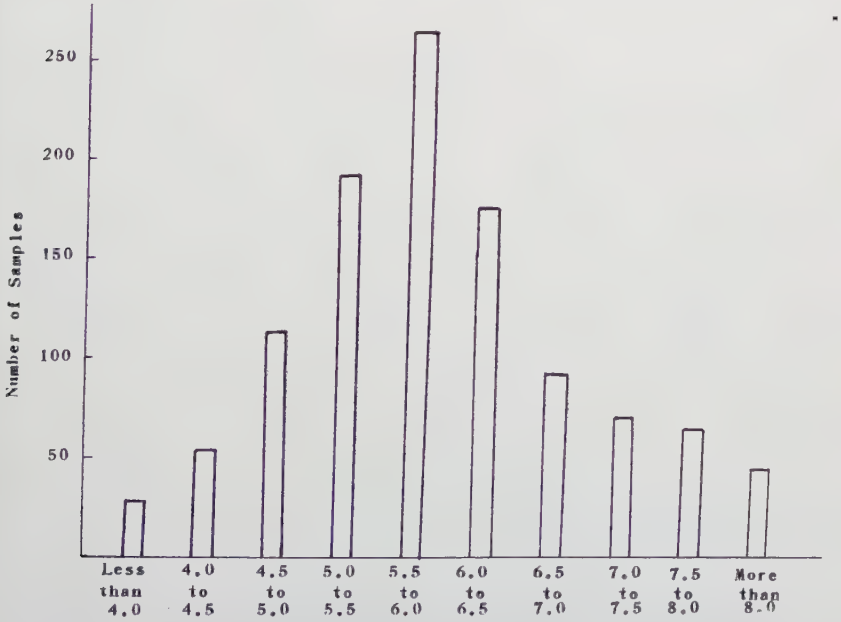

Figure 3.—pH Range of Soil Samples Sent to Soil Testing Laboratory 1945-1947.

between the amount of phosphorus extracted from Lakeland fine sand by carbon dioxide-saturated water and sodium acetate-acetic acid solution.

Calcium and potassium are now determined by the Flame Photometer. This made it necessary to use another extractant. Ammonium acetate buffered at pH 4.9 was adopted. Results of tests on field experiments (5, 10) at different rates of fertilization showed that any extractant gives empirical values which must be calibrated against crop response in field experiments on the soil type in question. Results (6) of experiments with radioactive phosphorus indicated that the amount of phosphorus extracted from certain soils by 0.002 N sulfuric acid correlated well with the uptake of phosphorus by plants growing on these soils in greenhouse pots.

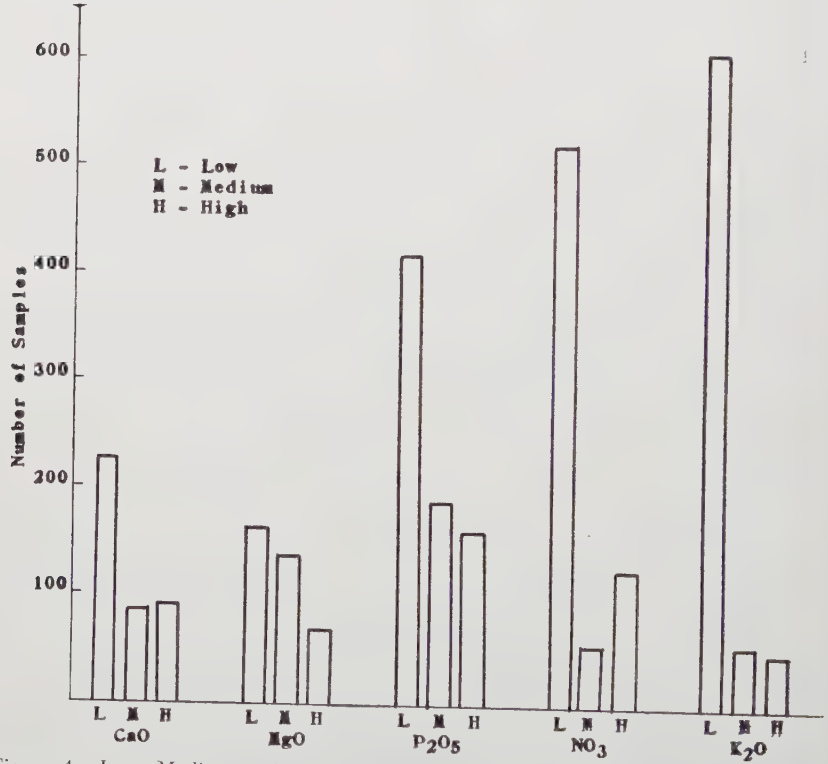

Figure 4.—Low, Medium and High Major Nutrient Levels in Soil Samples Sent to Soil Testing Laboratory 1945-1947.

SUMMARY AND CONCLUSIONS

It has been shown that the State-supported laboratories devote considerable of their facilities to soil testing as a service to farmers. The demand for such service has increased tremendously since the Experiment Station was established and this demand will, in all probability, increase still more. It is concluded that rapid laboratory tests need to be streamlined and made "more rapid" if this demand is to be met. Also, there

is an urgent need for a new "approach" to the problem of calibration of tests, correlation of test results with response, and the interpretation of test results.

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ROLE OF RESEARCH IN A SOIL TESTING PROGRAM

A. Utilizing Soil Tests as a Basis for the Determination of Optimum Levels of Phosphate and Potash for Crops Growing on Everglades Peat and Muck Soils

W. T. Forsee, Jr.*

The results of soil tests have been used for many years, with variously reported degrees of success, to arrive at more intelligent methods for making fertilizer recommendations for various crops. These "soil tests" have included various physical and chemical measurements and have ranged from accurately quantitative laboratory methods to simple kits that may be used in the field. The value of a number of soil testing kits has been investigated and reported by Spencer and Beckenbach (6). One of the most serious deficiencies of such soil testing methods is the lack of sensitivity within the lower fertility ranges where differences are most important for many crops. This and other weaknesses make soil test kits inadequate for use in arriving at recommendations for fertilizer treatment prior to planting. Quantitative laboratory methods are necessary for research where accuracy is required, but many such procedures are too long and involved for use in the analysis of large numbers of samples in a short time as is required for routine soil testing. During recent years laboratory procedures have been simplified and adapted to routine soil testing. The advent of the flame spectrophotometer has increased still more the speed and accuracy of handling large numbers of samples.

Soil test results referred to in this paper were obtained by rapid laboratory methods that were selected and modified over a period of several years to best fit the conditions imposed by soil type, climate and plant response under known or controlled conditions. Some of these factors have been reported previously (1). The method for estimation of the bases consisted of extracting 2 volumes of sieved, air-dry soil with 5 volumes of 0.5 N acetic acid. The flame spectrophotometer was used for determination of potassium, sodium, calcium and magnesium. Determination of phosphorus was made colorimetrically on an extract obtained from 2 volumes of soil in 25 of water.

With the exception of pH and certain other physico-chemical measurements, the values reported as the results of soil tests are entirely relative, depending upon several factors, among which are: choice of extracting solution, ratio of soil to extractant, time of contact between soil and extractant, physical condition of soil, and others. Because of these, the results of one test cannot be compared successfully with another unless the tests are made by identical procedures under the same general conditions. The results of any test must be utilized on the basis of previous tests that have been correlated with the response of the crop in question

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under similar conditions. With this in mind, experiments correlating crop yields with soil tests for pH, phosphorus and potassium on Everglades peat and muck soils have been conducted with celery (1, 2, 5), potatoes (1, 5), beans (4), cabbage (5), head lettuce (5), escarole (5), endive (5), broccoli (5), sweet corn (5), some grasses (1, 5), fiber crops (5), and field corn (3).

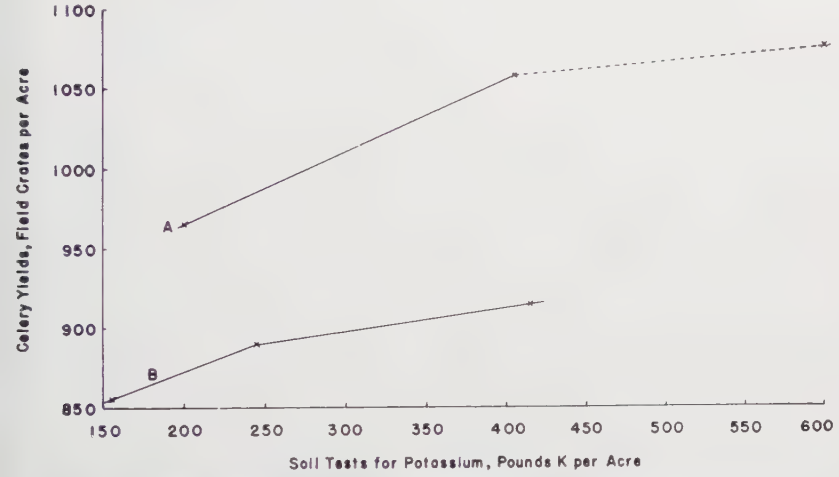

Figure 1. Yield of Celery at levels of potassium in the soil as determined by soil tests. Experiment A, Everglades Peat soil. Experiment B, Everglades Peaty Muck soil.

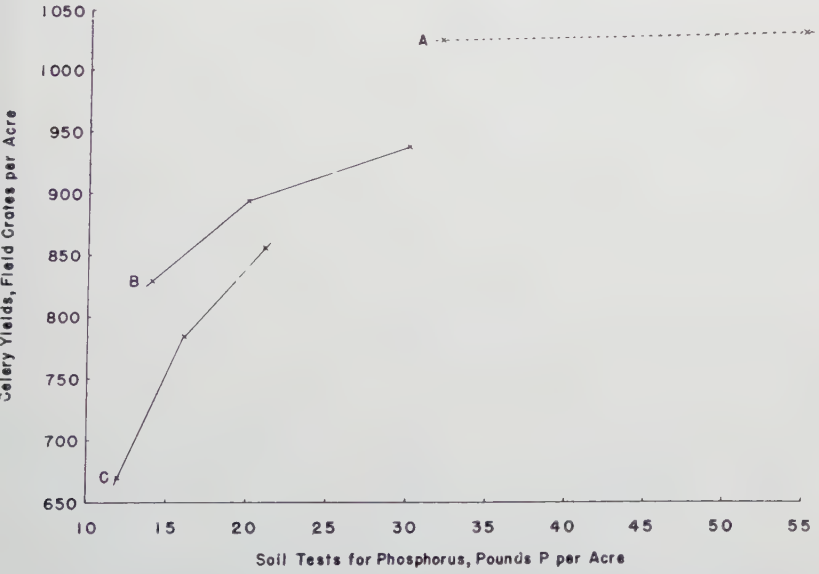

Figure 2. Yield of Celery at levels of phosphorus in the soil as determined soil tests. Experiment A, Everglades Peat. Experiments B and C, Everglades eaty Muck.

One of the objectives in the collection of data correlating soil tests with crop yields is to ascertain the level of an element in the soil—as determined by the soil test—above which no additional response may be obtained, assuming other factors to be as nearly optimum as is possible under experimental conditions. These values may be called "threshold levels". Such levels for the principal crops, along with some knowledge of the amount of fertilizer that must be applied in order to adjust any similar type soil to these theoretical levels, comprise the fundamental information necessary to effectively utilize the results of soil tests in making fertilizer recommendations. This information has been obtained for the previously mentioned crops from experiments usually involving two or three factors at various levels and laid out in randomized block or factorial designs. Several experiments for a single crop conducted over a period of two or three years have in most cases given sufficient corroborative data to establish "threshold levels" for that crop. A summarized review of data previously published in some detail for celery (2), beans (4), and field corn (3), is made in this paper to establish "threshold values" for these crops growing on Everglades organic soils.

The response of celery to potash is shown in Figure 1. The points on the graphs are averages representing levels established in the experiments by broadcast applications of muriate of potash before the celery was transplanted. The levels indicated are the averages of soil tests from all plots receiving the same rate of potash treatment. Points connected by solid lines are statistically different at the 5 percent point. Those not statistically different are connected by dotted lines. Celery yields increased statistically up to a potassium level of approximately 400 to 450 pounds K per acre as determined by the soil tests. Thus, 450 pounds K per acre may be taken as the "threshold level" for celery. Subsequent experiments have indicated the same yield response to 80 percent of the amount of fertilizer when applied one-half at planting and one-half side dressed in two applications. Hence, in making fertilizer recommendations a "threshold level" of 350 pounds for K may be assumed.

Variations in celery yields with respect to phosphorus levels as determined by soil tests are shown in Figure 2. The graphs represent data from three experiments and indicate a rather sharp response beginning at the lowest level of 12 pounds P and gradually decreasing as the level approaches 30 to 35 pounds per acre. A very close agreement between the yield differences at approximately similar phosphate levels may be noted in the parallel portions of graphs B and C. This is particularly indicative of an accurate representation of yield response because the experiments were conducted during two different years. Thus, the "threshold level" of phosphorus for celery seems to be 30 pounds P per acre.

Yield data for snap beans relative to potassium levels are recorded in Table 1. There is a trend toward increased yields to potash applications up to residual levels in the soil of 80 pounds K per acre, the probable "threshold level" for this crop. At the higher potash levels the yield trend is downward with applications of potash, particularly at the higher rates. Yields relative to phosphate levels are recorded in Tables 2 and 3. The data recorded in Table 2 represent responses to two rates of phosphate treatment at phosphorus residual levels in the soil encountered for four experiments and indicate a "threshold level" for phos-

phorus slightly above 4.7 and less than 15 pounds P per acre. The data in Table 3 indicate a "threshold level" of approximately 6.5 pounds P per acre. Since these "threshold values" for P and K have been tentatively established, many fertilizer recommendations for beans based on the results of soil tests have been made with apparent success even to the point of recommending no fertilizer when such was indicated by the tests.

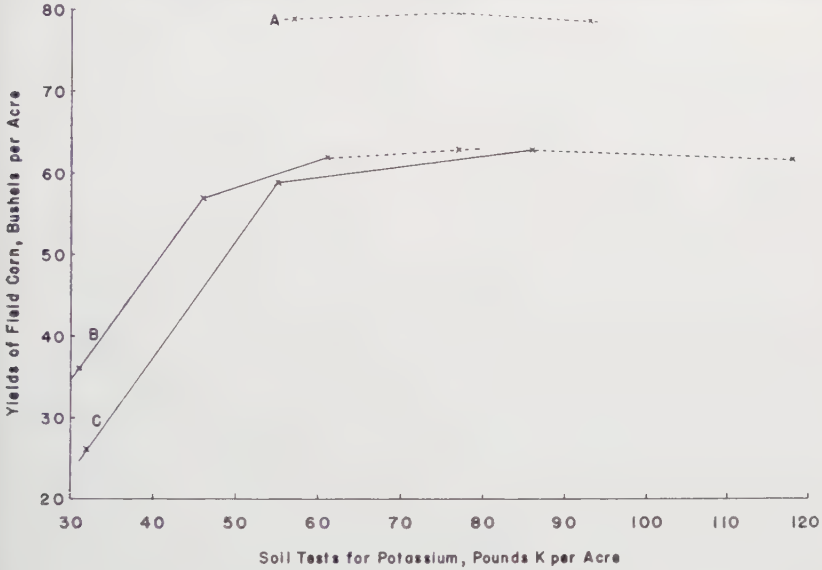

Figure 3. Yields of Field Corn at levels of potassium in the soil as determined by soil tests. Experiments A, B and C on Everglades Peaty Muck Soil.

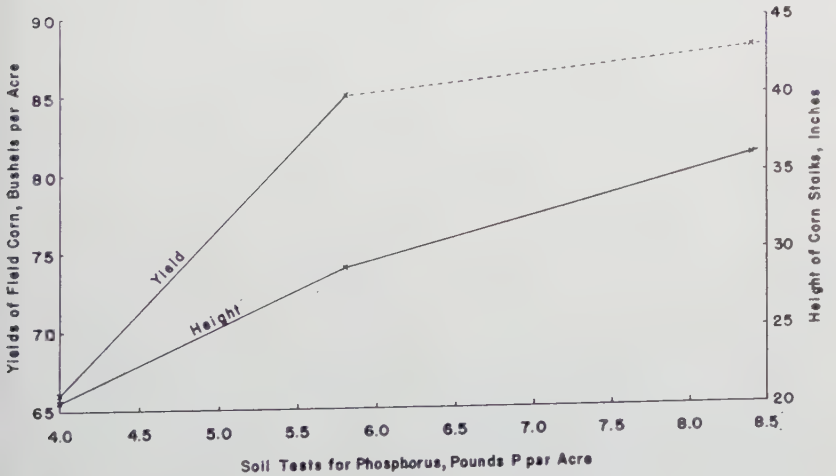

Figure 4. Yield and Height of Field Corn at levels of phosphorus in soil as determined by soil tests.

TABLE 1.—Average Yields of Snap Beans in Six Experiments Conducted on Organic Soils of Known Residual Potassium Levels Determined by Soil Tests.

Residual Potassium, Lbs. per A	Yield in Bushels per Acre				
	No K_2O*	30 Lbs. K_2O*	48 Lbs. K_2O*	60 Lbs. K_2O*	96 Lbs. K_2O*
47	146	177	.....	169	
61	245	.....	237	.....	229
81	156	.....	165	.....	175
82	190	178	.....	187	
105	194	.....	191	.....	166
123	118	.....	126	.....	103

* Pounds applied per acre. Derived from 60 percent muriate of potash.

Yield curves for field corn with respect to potassium in the soil as determined by soil tests are shown in Figure 3. These represent three experiments conducted during the same season at two locations on Everglades peaty muck soil. These data indicate a potassium "threshold level" of approximately 60 to 80 pounds K per acre. Although there were no yield differences in experiment A, height measurements taken

TABLE 2.—Average Yields of Snap Beans in Four Experiments Conducted on Organic Soils of Known Residual Phosphorus Levels.

Residual Phosphorus, Lbs. per A	Yield in Bushels per Acre		
	No P_2O_5*	32 Lbs. P_2O_5*	64 Lbs. P_2O_5*
3.6	99	121	128
4.4	129	182	184
4.7	176	198	182
15.0	233	221	241

* Pounds applied per acre. Derived from 20 percent superphosphate.

early during the growth of the plants indicated a statistically significant difference between levels represented by points 1 and 2. This indicates an optimum level of approximately 75 pounds K per acre. Yield curves with respect to phosphorus are shown in Figure 4. These data are the result of one experiment conducted on Everglades peaty muck soil. Yields of corn increased significantly up to approximately 6 pounds water-soluble P per acre with smaller increases up to 8 pounds. There was a highly significant increase in plant growth from the 6- to 8-pound level as indicated by height measurements made during the early growth of the plants. These growth differences decreased as the crop matured. Two experiments not shown in the figure showed no yield responses as soil

phosphorus was increased from 8.8 to 18.0 pounds P per acre. Thus, the combined data seem to indicate a phosphorus "threshold level" of approximately 8.0 pounds P per acre for field corn.

TABLE 3.—Average Yields of Snap Beans Grown at Three Levels of Soil Phosphorus Established by Applications of Superphosphates and Determined by Soil Tests.

Phosphorus in Soil Lbs. per Acre	Bean Yields Bushels per Acre
4.4	129
6.3	182
8.6	184

During these experiments soil samples were collected from all plots prior to fertilizing and again several days after broadcast applications of the fertilizer. This afforded opportunity to determine the effect of adding various increments of phosphorus and potassium on the resulting soil tests by the procedures in use. There was considerable variation within wide limits but the large number of individual treatments allowed the estimation of averages that could be used in making fertilizer recommendations. It was found that an application of approximately 2 pounds of K_2O was required to increase the results of a soil test for potassium by an amount of 1 pound K per acre and an application of 20 pounds of P_2O_5 was required to raise the soil test for phosphorus the amount of 1 pound P per acre.

With the foregoing information concerning "threshold levels" and some estimate as to the amount of fertilizer required to raise the content of the soil to a required level, a fertilizer recommendation may be made with reasonable assurance that the actual requirements of the growing crop will be supplied without the waste involved where much more than the required amounts are applied. For example, suppose it is desired to grow a crop of field corn on an Everglades peaty muck soil that had been analyzed by the procedures used in the previously described experiments and the soil tests indicated phosphorus and potassium levels of 4 and 25 pounds per acre, respectively, of P and K. From the experiments already conducted it has been determined that the "threshold levels" of P and K for field corn are 8 and 75 pounds per acre, respectively. The phosphorus level must be raised from 4 to 8 pounds, an increase of 4 pounds per acre. Experiments have indicated that 20 pounds of P_2O_5 per acre are needed to raise the phosphorus level 1 pound. Thus, 80 pounds P_2O_5 should be applied for a crop of corn. Likewise, the soil test for potassium must be raised from 25 to 75 pounds K per acre. Since 2 pounds of K_2O are required to raise the K test 1 pound, it would require 100 pounds of K_2O to raise the potash to the level required for field corn. The 80 pounds of P_2O_5 and 100 pounds of K_2O could be supplied by applying 600 to 700 pounds per acre of an 0-12-16 fertilizer mixture.

Experience has indicated that it is entirely safe to recommend the application of no fertilizer when the tests indicate adequate amounts of

P and K for a crop on the basis of previous fertilizer experiments. In making fertilizer recommendations on the basis of soil tests, standard mixtures that most nearly fit the estimated requirements should be suggested rather than exact formulations. Standard mixtures are usually lower in price and more readily purchasable.

As a result of many experiments of this type, it is now possible to make accurate fertilizer recommendations for most crops on the basis of soil tests made on representative soil samples collected from the proposed site of the crop. The soil tests must be conducted according to the identical procedures used for the experiments and the soil should be of the same general type. There is no substitute for information gained through experience. For this reason the recommendations should be made by persons entirely familiar with local conditions as well as with the experiments used as a basis for the recommendations.

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ROLE OF RESEARCH IN A SOIL TESTING PROGRAM

B. Sampling Soils on a Field Basis

W. L. Pritchett, H. L. Breland, and W. D. Hanson*

There has been a great increase in interest in soil testing in recent years. As a means of soil characterization and predicting fertilizer needs, soil testing has a great appeal to the farmer, as indicated by the 1½ million samples analyzed last year in this country. However, in spite of the flood of publicity, often claiming the soil test as a cure-all for crop problems, it should be used with some caution.

The rapid soil test as a basis for making fertilizer recommendations for a particular area has a number of inherent weaknesses. One of these weaknesses is the assumption that the sample of soil tested is representative of the field sampled. The difficulties in securing a composite sample, representative of the area sampled, have been generally recognized (2, 7, 10, 6, 9). It is agreed that for soils the error in sampling is commonly much greater than the analytical error. This probably results from the heterogeneous nature of the soils and from the greater effort placed on devising new methods or improving existing methods of analyses than on sampling methods.

Some investigations have been conducted on sampling technique for small areas, usually experimental plots of a fraction of an acre (1, 4). However, very little research has been reported on sampling of large fields, such as are dealt with in a service testing laboratory. The exception is work on probable error of sampling in soil surveys (11).

Few conclusions and little agreement are reported on the correct techniques, even on small areas. One of the earlier recommendations (1895) for sampling employed a metal frame, one foot square. This was driven into the ground to a depth of nine inches, and the soil contained within constituted the sample (13). Somewhat later a need for more intensive sampling was recognized. It was suggested (1) in 1920 that a composite should be made up of 20 samples, each taken to a depth of 12 inches, for each 1/20 of an acre. Other investigators have stressed the importance of uniform depth (5, 12), or the time factor (1, 6) in sampling. Little attention was given to the size of area to be sampled, the number of borings to constitute a composite sample, or the number of composite samples per given area.

More recently, attempts have been made (2, 3, 8) to list procedures to follow in taking soil samples under specified conditions. It has been reported that sampling the upper six inches of soil should be sufficient for most cultivated annual crops, since this comprises the active part of the soil and the zone of feeder-root concentration of most plants. However, it has been generally suggested that permanent pastures and lawns be sampled to a depth of two to three inches.

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Fall or early spring is recommended as the best time for pre-fertilization sampling. This is probably a practice based on convenience rather than results of investigations. Sufficient time should elapse before sampling for the top soil to reach equilibrium following a heavy application of lime or fertilizer. This time lag may be from six months to a year after application.

It has been pointed out that a single composite sample is justified if an unbiased estimate of the mean fertility level is the sole objective in sampling. However, if information on field variation is sought, more than one composite must be drawn. This means that the individual composites must be taken from distinct parts of a field, and when a fertility gradient exists the area should be divided into strata. A sample that consists of units from two distinct populations is representative of neither. Separating heterogeneous populations into homogeneous strata is a means of reducing the number of samples per area.

The number of composite samples, the number of cores per composite, the manner of composting and subsampling the soil collected, and the laboratory technique used will be influenced by the purpose for which the sample is taken. Each property of the soil may have a different pattern of variation in the field, so that the number of cores will be determined by the property requiring the greatest intensity of sampling.

The difficulties of taking large composite samples and then subsampling from them in the field has been pointed out, especially with heavy and wet soils. A solution suggested (8) was that the individual borings should be small enough so that the entire composite sample could be submitted to the service laboratory. However, it is reported (10) that drawing of small subsamples from dry, well-mixed soil, ground to pass a 40-mesh sieve, does not constitute a major source of error.

An adequate sample of an area, to be sure, is influenced by a number of factors. The number of samples may have to be a compromise between the minimum desired for accuracy and that required for economy.

While these past studies on plot sampling have contributed greatly toward improving the technique of soil sampling, it would probably be unwise to expand the results, in all cases, to fields of several acres in size, such as encountered in sampling for a service laboratory.

In view of the need for more information on field sampling for service laboratories, as pointed out by the Soil Testing Work Group, some preliminary studies were initiated. The purpose of these was to contribute to the meager information on sampling technique in general, with particular emphasis on number of borings for an adequate composite sample and the size of area that might be sampled separately.

METHODS

Three fields were sampled as representative of some different soil types and cropping systems encountered by a service laboratory. All fields were sampled during late fall and treated according to current recommendations.

Field I. Orangeburg fine sandy loam of relatively high fertility. This eight-acre field had been cultivated to corn during the past three years and had an annual drill application of 400 pounds of 5-7-5 fertilizer per acre. No limestone or manure had been applied during this time. The

area had been plowed prior to sampling. It was slightly rolling, but was uniform in appearance.

Field II. Rex fine sand seeded to pangola grass. This seven-to-eight acre field had been used as pasture for the past 10 years. It had received only one light application of a complete fertilizer in recent years. The pasture, although level and rather uniform in appearance, was variable due to manure and urine spots.

Field III. This field of Arredondo fine sand had been under cultivation for several decades. This area of about four acres was slightly rolling and rather non-uniform. It was seeded to fall oats and the plants were about three inches high when the soil was sampled. This area was of medium fertility and had received a broadcast application of about 500 pounds per acre of 5-10-10 fertilizer about two months before sampling.

In fields I and II, individual samples were taken from 36 equally spaced positions in each. The cores were taken with a soil tube to a depth of six inches in the cultivated fields (I and III) and to a depth of three inches in the pasture area (Field II). Six cores were taken within a foot radius and composited at each position to secure sufficient soil for analyses at each position.

Fifteen cores were taken at random over the entire area on Field III and composited. This was repeated nine times. Composites were mixed in clean gallon containers and three subsamples were drawn from each in the field. The 27 subsamples were air-dried in the laboratory, ground to pass a 1-mm. sieve, mixed and again subsampled for chemical analyses. This enabled a determination of errors due to field sampling, to subsampling of the moist soil in the field, to subsampling of dry, mixed soil in the laboratory, and to laboratory technique.

The methods used in the chemical analyses of the samples were standard methods for the service laboratory and were all adapted to a single leaching solution. An acid (pH 4.8) solution of ammonium acetate was used for leaching the soil. A soil:solution ratio of 1 to 5 was used and the different determinations were then made on the extract.

Calcium—(Quantitative) Determination was made on a Beckman, model B, flame photometer.

Potassium—(Quantitative) Same method as for calcium.

Phosphorus—(Quantitative) The ammonium molybdate and stannous chloride method was used. The resulting blue color was read in a photoelectric colorimeter.

Magnesium—(Qualitative) Titan yellow and sodium hydroxide method was used. The resultant red color was visually compared with standards.

Nitrates—(Qualitative) Diphenylaminesulfonic acid was used to develop a blue color, the intensity of which was visually compared with standards.

pH—This determination was made by using a glass electrode and a suitable potentiometer. A soil: water ratio of 1 to 2 was allowed to stand at least 40 minutes before reading.

Magnesium and nitrate determinations were made on all samples. However, as the values were uniformly low they were not included in this study.

TABLE 1.—Determinations of pH, and Calcium, Phosphorus and Potassium in Pounds Per Acre in Field III.

Composite Sample	Field Subsample	pH Lab. Subsample		CaO Lab. Subsample				P_2O_5 Lab. Subsample				K_2O Lab Subsample			
				1 Aliquot		2 Aliquot		1 Aliquot		2 Aliquot		1 Aliquot		2 Aliquot	
		1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	1	5.88	5.82	658	658	630	630	41	39	39	39	102	99	99	96
	2	5.88	5.94	630	630	630	630	38	38	37	37	78	78	84	84
	3	5.92	5.90	658	658	658	658	39	38	37	37	78	78	84	84
2	1	6.02	6.10	700	700	700	700	44	41	39	41	132	132	138	138
	2	6.04	6.05	770	770	728	728	44	46	43	44	138	138	126	126
	3	6.10	6.10	728	728	728	728	42	39	38	38	126	126	126	126
3	1	6.10	6.10	364	364	364	364	32	31	31	31	84	90	84	96
	2	6.00	6.00	364	364	364	364	32	32	41	41	96	96	96	96
	3	6.12	6.00	364	364	364	364	34	33	32	33	96	96	93	93
4	1	6.12	6.08	392		336		27		31		94		96	
	2	6.20	6.10	322		350		30		31		90		88	
	3	6.10	6.08	350		350		24		24		88		88	
5	1	6.10	6.20	458		490		37		37		76		74	
	2	6.12	6.10	322		322		33		33		71		66	
	3	5.80	6.00	280		280		26		26		66		66	
6	1	5.90	6.00	322		322		36		36		79		79	
	2	6.02	5.92	322		322		30		31		88		84	
	3	6.00	6.00	252		280		31		31		76		84	
7	1	6.10		350	350			32				77	77		
	2	6.10		406	406			33				73	73		
	3	6.02		378	378			37				77	77		
8	1	6.18		476	476			32				116	116		
	2	6.22		448	448			31				102	102		
	3	6.18		476	476			33				106	106		
9	1	6.10		378	378			29				88	88		
	2	6.00		378	378			27				90	90		
	3	6.10		322	322			29				90	84		

RESULTS AND DISCUSSION

One of the objectives of this study was to determine the error associated with subsampling in the field from a composite sample of soil. Present recommendations instruct the farmer to take a sample composed of 12 to 15 borings from a field and to draw a pint subsample from the well-mixed composite for sending to the laboratory. In order to isolate this subsampling error, the variation due to the different steps involved in determining the chemical properties of a soil were studied. These variances are due to (a) location-to-location variations within the field, (b) subsampling of the composite sample in the field, (c) subsampling of the soil sent to the laboratory, (d) and variation due to the laboratory procedure.

As previously mentioned, nine separate samples were taken from Field III. Each sample, a composite of 15 borings, was mixed and subsampled three times in the field. These 27 subsamples were again subsampled in the laboratory after drying and thorough mixing. An irregular sampling schedule was adapted to obtain a satisfactory degree of freedom for field sampling and laboratory sampling without requiring a large number of determinations. These results arranged according to the sampling schedule are given in Table 1. The statistical analyses of these data are given in Table 2. Since the number of determinations made on each sample and field subsample varied, the number of degrees of freedom also varied.

TABLE 2.—Analyses of Variance of pH, Calcium, Phosphorus and Potassium Deteminations on Soil from Field III.

Source of Variation	pH		Calcium		Phosphorus		Potassium	
	Degrees of freedom	Mean Square	Degrees of freedom	Mean Square	Degrees of freedom	Mean Square	Degrees of freedom	Mean Square
Total	44		71		62		71	
Location composites	8	.0340	8	216,670	8	154.0	8	3,107.9
Field subsampling ..	18	.0064	18	3,411	18	19.1	18	88.8
Labortory subsampling ..	18	.0031	18	300	18	6.2	18	18.8
Chemical analysis			27	0	18	0.4	27	4.3

The composition or expectation for the mean square in the analysis is given in Table 3. The components follow the irregular sampling pattern. The estimated components of variance associated with each source of error are given in Table 4 together with the percentage distribution of the variance for a determination based on a composite sample of 15 boring locations, one field sample, one laboratory sample and one laboratory determination. In most cases the variation of a determination is associated with the variation of locations in the field, while the error arising

from subsampling of the composite in the field is appreciably smaller. The errors associated with drawing a laboratory subsample and making the chemical analyses are quite small in comparison to the total variation.

The percentage distribution of variation for the steps involved in determining the different soil properties are given in Table 4. It is interesting to note that the percent variations arising from locations in the pH and phosphorus determinations are considerably lower than those for calcium and potassium. This does not necessarily mean that the laboratory procedures for these determinations are less accurate, but that their more even distribution in the field make for more accurate sampling.

TABLE 3.—The Composition of Mean Squares (Expected Mean Squares) for the Respective Analyses Given in Table 2.

Source of Variation	Composition of Mean Squares		
	pH	Phosphorus	Calcium and Potassium
Location Composite	Vls + 1.65 Vfs + 4.94 Vlc	Va + 1.30 Vls + 2.25 Vfs + 6.75 Vls	Va + 1.66 Vls + 2.62 Vfs + 7.88 Vlc
Field Sample	Vls + 1.67 Vfs	Va + 1.33 Vls + 2.33 Vfs	Va + 1.67 Vls + 2.67 Vfs
Laboratory Sample	Vls*	Va + 1.50 Vls	Va + 1.50 Vls
Chemical Analysis		Va	Va

Va, Vls, Vfs, and Vlc are variances due to chemical analyses, laboratory subsampling, field subsampling, and location-to-location variation, respectively.

* Vls contains errors resulting from laboratory subsampling and analytical errors.

Since a large percent of the total error is associated with variations at boring locations in the field, any procedure which will reduce this error will greatly increase the precision of the samplying technique. The precision of a sampling method can be predicted as follows on the basis of random sampling:

$$V\bar{x} = \frac{Vlc}{lc} + \frac{Vfs}{fs} + \frac{Vls}{ls} + \frac{Va}{a}$$

where the estimated true variances are divided by the number of location composites, field subsamples, laboratory subsamples and analyses per composite sample.

One method of reducing the variance would be to composite or combine a number of composite samples and make one determination from one field sample. This is in effect increasing the number of borings per composite. Combining six composite samples or using 90 borings ($6 \times 15 = 90$) would reduce the variation from 422.9 to 103.5 in the case of the potassium determination, as shown:

$$V\bar{x} = \frac{383.53}{6} + \frac{25.65}{1} + \frac{9.61}{1} + \frac{4.33}{1} = 103.5.$$

However, a more practical method would be to analyze the composite samples separately. Three composite samples with one analysis of each would reduce the estimated error to 141.04 in the above example. While taking more than one composite sample increases the effort on the part of the farmer, it appears that the increased sampling precision would justify at least two composite samples under most conditions.

TABLE 4.—The Estimation of Variance Components in Soil Sampling Together with the Percentage Distribution of Variation for a Single Determination Made on a Field Composite.

Variance Component	pH		Calcium		Phosphorus		Potassium	
	Value	%	Value	%	Value	%	Value	%
Vlc	.0056	52.3	27,071	95.2	20.1	66.6	383.8	90.6
Vfs	.0020	18.7	1,152	4.1	5.8	19.2	25.6	6.1
Vls	.0031	29.0	200	0.7	3.9	12.9	9.7	2.3
Va			0	0.0	0.4	1.3	4.3	1.0
Total	.0107	100.0	28,423	100.0	30.2	100.0	422.9	100.0

It will be recalled that Fields I and II were each sampled systematically at 36 locations. The samples from each location were analyzed separately so that an accurate determination of variation in the fields could be made. Any pattern or fertility gradient would also be encountered by this means. The data (Table 5) were then statistically analyzed on the basis of area size. The data from the chemical analyses were divided in seven area sizes: (a) the whole area of about eight acres with 36 borings, (b) two portions of four acres with 18 borings in each, (c) three equal areas of about 2.6 acres each with 12 borings in each, (d) four areas of two acres with 9 borings, (e) six areas of about 1.3 acres with 6 borings in each, (f) nine areas of about 0.9 acres with four bearings, and (g) 18 areas of approximately 0.44 acres with two boring locations in each area.

The levels of potassium in the pasture area (Field II) were extremely variable. This could have been caused by urine spots. This condition is probably not unusual in pastures that are heavily grazed and consequently cannot be ignored. However, since the analyses of these data would have little meaning, the square roots of the determinations were taken.

The analyses of variance of the four determinations are given in Table 6.

From these data it can be seen that the variances of the levels of the four soil properties differ greatly in their magnitude. The determination of pH and phosphorus can be measured more accurately in these soils, for example, than can calcium and potassium. However, the magnitudes of the variances of any one property do not differ appreciably from one size area to another except to exhibit a trend of reduced variability with reduced area. This means that under the conditions studied, a one-half acre field would need to be sampled almost as thoroughly as an area of eight acres or more. This can be explained from the fact that little or no fertility

gradient was observed or the gradient was marked by location variability. The differences within the divisions were about as great as those between the divisions. To illustrate this more clearly, the number of borings, or locations, per area necessary to give a desired precision was determined. Since each soil property does have an independent variation, the number of borings needed for each property were made (Table 7). The property requiring the greatest accuracy will dictate the intensity with which a field is sampled, since one composite sample of soil is usually used for the determination of a number of properties.

TABLE 5. Determination of pH, Calcium, Phosphorus, and Potassium in Pounds per Acre on Individual Boring in Fields I and II.

Boring Number	Field I				Field II			
	pH	Calcium	Phos-phorus	Po-tassium	pH	Calcium	Phos-phorus	Po-tassium
1	5.32	140	5	84	5.75	440	9	36
2	5.32	490	5	96	5.32	126	11	19
3	5.29	182	5	60	5.70	84	5	67
4	5.03	70	5	66	5.80	252	10	78
5	5.17	140	5	84	5.85	84	14	55
6	5.27	560	5	90	6.50	126	12	324
7	5.37	280	11	72	5.40	210	9	51
8	5.17	224	2	96	5.85	126	5	48
9	5.27	182	3	132	6.30	308	13	313
10	5 30	224	6	108	5.82	378	9	55
11	5.30	280	15	84	5.45	616	5	31
12	5.27	308	4	180	5.75	308	12	42
13	5.30	630	13	120	5.00	658	3	31
14	5.08	140	2	84	5.10	616	7	55
15	5 05	28	2	90	5.10	533	3	42
16	5.18	98	1	90	5.50	533	14	48
17	5.10	28	4	102	5.22	700	13	31
18	5.17	182	2	102	5.60	308	10	24
19	5.17	70	2	90	5.35	336	1	31
20	5.30	350	21	90	5.40	440	9	36
21	5 17	182	2	84	5.02	440	14	67
22	5.18	98	1	66	6.00	574	1	442
23	5.18	70	4	84	5.05	574	9	28
24	5.13	182	7	120	5.05	440	3	19
25	5.01	98	3	84	5.15	308	11	31
26	5 06	70	1	66	5.92	126	9	19
27	5.22	140	3	102	5.50	490	16	42
28	5.22	98	1	84	5.25	490	12	48
29	5.27	224	4	84	5.32	658	16	48
30	5.13	140	1	72	5.52	616	21	55
31	5.05	98	2	66	5.65	533	12	72
32	5.22	140	2	66	5.55	616	9	72
33	5.34	140	4	66	5.72	533	14	42
34	5.23	490	6	132	5.72	440	10	36
35	5.13	10	2	72	5.85	210	3	42
36	5.30	28	4	60	5.75	35	7	24

In a fairly uniform field, such as the cultivated area in this study, a rather high degree of accuracy for all four properties could be obtained by taking borings in about twenty-five locations. The mean soil reaction, for example, could be measured to within plus or minus 0.1 pH with only

four locations at the 0.5 level of confidence on this field. To measure phosphorus with an accuracy within five pounds per acre would require a similar number of samples. However, to determine calcium within 60 pounds, and potassium within 10 pounds per acre, would require about 25 borings. However, the low values for phosphorus in these fields as compared to calcium or potassium, may also help explain the small number of borings needed for an adequate composite sample. In other words, relatively few samples vary more from the mean than the five pounds of phosphorus per acre, set up as the desired limit of accuracy for this element.

TABLE 6.—Mean Squares of the Determinations on Fields I and II.

Source	Degrees of Freedom	Field I (Cultivated Area)				Field II (Pasture Area)			
		pH	Calcium	Phosphorus	Potassium	pH	Calcium	Phosphorus	Potassium
8 acres	35	0.0089	22816	18.1	594	0.1279	380,153	23.7	13.58
4 acres	34	0.0091	21594	16.5	550	0.1276	374.085	21.4	13.89
2.6 acres	33	0.0091	22034	18.1	586	0.0883	278,914	21.6	13.58
2 acres	32	0.0079	19754	17.1	535	0.1170	338,737	20.9	13.61
1.3 acres	30	0.0085	19423	14.2	570	0.0831	181,880	17.8	11.88
0.9 acres	27	0.0099	21725	17.5	628	0.0828	136,971	18.0	11.71
0.4 acres	18	0.0084	22724	20.6	526	0.0870	144.058	22.0	11.14

The pasture area is rather non-uniform and to sample with the same degree of accuracy used in the cultivated field would require a much larger number of locations, except in the case of phosphorus which appears to be rather uniformly distributed in both fields. Calcium measured to within 100 pounds per acre of CaO would require from 63 to 157 borings, depending on the area size. These estimates of boring number appear to be over estimated since the distribution of the CaO determinations does not appear to follow the normal distribution. Calcium determinations are highly variable and the number of borings required to achieve the level of precision is impracticable; hence under normal conditions, the level of accuracy must be sacrificed. As would be expected, sampling for potassium under pasture conditions requires a large number of samples for accuracy.

Phosphorus and pH determinations are commonly of greater importance in soil samples for fertilizer recommendations than are the other properties. If this is assumed to be true, some of the accuracy in determining calcium and potassium might be reduced for economy's sake, without greatly affecting the overall value of the sample, by reducing the number of locations per composite. In this case 12 to 15 borings would make an adequate composite sample if the field were dvided into two or more areas and a composite sample taken from each area.

TABLE 7.—Number of Locations Needed for Specified Limits of Precision with Varying Size of Area (Fields I and II).

Size of Area, Acres	pH		Calcium			Phos. phorus	Potassium			
	Limits of Accuracy*									
			Pounds/Acre			Pounds/ Acre	Pounds/Acre			
	.01	0.2	50	100	200	5	10	15	20	25
Field I										
8	4	1	38	9		3	24	11		
4	4	1	36	9		3	23	10		
2.6	4	1	36	9		3	24	11		
2	4	1	33	8		3	22	10		
1.3	4	1	32	8		3	24	11		
0.9	4	1	36	9		3	26	12		
0.4	4	1	40	10		4	23	10		
Field II										
8	53	13		157	39	4			32	21
4	53	13		154	39	4			33	21
2.6	37	9		115	29	4			32	21
2	49	12		141	35	3			33	21
1.3	35	9		76	19	3			29	18
0.9	35	9		58	15	3			28	18
0.4	38	10		63	16	4			28	18

* Limits of accuracy are given at the 0.05 confidence intervals.

To illustrate the value of dividing a field into two or more parts and taking a separate composite sample from each, the expected limits of accuracy were calculated using a varying number of composite samples. These values for one to four soil sample composites per area were calculated on the basis of 15 locations per composite. The limits of accuracy for pH determinations, for example, can be reduced from 0.23 with one composite to 0.16, 0.13, and 0.11 with two, three, and four composited samples, respectively.

Number of Composites	*pH* Units	*Calcium*	*Phosphorus* Pounds per Acre	*Potassium*
1	0.23	372	12	45
2	0.16	262	9	32
3	0.13	215	7	26
4	0.11	185	6	23

If the field exhibits a fertility gradient, it should be divided so that the minimum variation appears within each area. It would appear from these data that uniform areas somewhat larger than the eight acres in these fields could be sampled about as accurately as small fields.

SUMMARY

Three fields, representing one relatively heavy soil and one light soil under cultivation and one sandy soil in permanent pasture, were included in a study of soil sampling on a field basis. The fields ranged from four to eight acres in size and were all relatively level and uniform in appearance.

From one cultivated field nine composite samples, consisting of 15 borings at random locations, were taken. These composite samples of moist soil were mixed and subsampled in the field and the 27 field subsamples were again subsampled in the laboratory after drying and grinding. Determinations for pH, calcium, phosphorus, and potassium were made in duplicate using the standard procedures of the service laboratory. These data were statistically analyzed to isolate the percent error associated with each step in determining the soil properties. The variation due to laboratory analyses and subsampling was found to be quite small in comparison to the location-to-location variation in the field. Drawing of pint subsamples of sandy soil from a larger composite sample in the field did not constitute a large error under the conditions studied. The error in field sampling probably can be most easily reduced by taking two or more composite samples from different sections of the field.

One cultivated field and one pasture area were systematically sampled by taking borings at 36 locations. The soil from each boring was analyzed separately. These data were statistically treated to approximate the number of borings needed to determine four soil properties at desired levels of accuracy in areas of different sizes. There appeared to be little correlation between locations. This probably explains why the number of locations needed for a desired precision did not vary greatly with area size. The cultivated area was more uniform than the pasture area. Urine spots in the pasture probably explain the extremely high potassium in three locations. In this study, the number of location borings necessary for reliability, within specified limits of accuracy, was found to be less for pH and phosphorus than for calcium and potassium. Since the former are of more importance in service sampling, some accuracy may be sacrificed in the determination of the latter for the sake of economy by reducing location borings in a given area.

Twelve to fifteen borings per composite sample are probably adequate for uniform areas of any size up to eight to twelve acres. However, two or more composite samples should be taken from separate parts of the field. Fields showing a fertility gradient should be divided into the most uniform areas.

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ROLE OF RESEARCH IN A SOIL TESTING PROGRAM

C. Some Important Uses of Tissue Testing

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The use of tissue testing as an aid to the understanding of nutritional disorders in plants had been reported in continental Europe prior to 1900. Ulrich (19) stated that De Saussure as early as 1804 found that the composition of the ash of plants varied with the age of plants and with the soil upon which the plant grew. Later Hall (10) of Rothamstad used plant analysis in the determination of the "normal nutrient" requirement of the plant.

In this country tissue testing has been more of a recent practice. Goodall and Gregory of England (9) state that great interest has been stimulated during the past twenty-five years in studies on plant analysis for diagnostic purposes. They attributed this expansion to several causes. Among them have been the recognized importance of deficiencies of the trace elements, increased studies with horticultural crops and improvements in analytical techniques. A fourth reason was listed as the interest shown in the nutritional condition of the plant irrespective of its relation to nutrient supplies in the soil.

Plant tissue testing may be roughly grouped into three types: One is the so-called "quick-test" method for green tissue as exemplified by the Purdue tissue testing kit developed by Thornton, et al (16). The second method used is more quantitative than that previously mentioned and is represented by procedures similar to Hester's (11) in which fresh tissue is treated in a Waring blendor in the presence of an extracting solution. The third type employs a total analysis of the tissue in studying the nutrition of plants.

This report will deal primarily with some important uses of tissue testing.

USES OF TISSUE TESTING

First let us review some of the past work on testing involving fresh plant tissue. The theory behind fresh or green tissue testing is that the portions estimated are materials which had recently entered the plant and that their concentration thus represents the current rate of nutrient intake.

Perhaps the greatest use of green tissue testing has been as an aid for diagnosing nutritional disorders in plants. For example, Hoffer (12) reported iron accumulation in the nodes of corn when the supply of available soil potassium became deficient. His "quick-test" method comprised of splitting the stalk lengthwise and adding an acidulated solution of potassium thiocyanate. Lynd (13) stated that green tissue tests are widely used in detecting nutrient deficiencies in plants previous to the time when visual symptoms are noticeable and that they are also useful in detecting changes in nutrient composition during a growth season. Scarseth (15) also reported that tissue tests will indicate a nutrient de-

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ficiency before the plant shows the starvation symptoms. Both Lynd (13) and Carolus (1) correlated green tissue tests with fertilizer treatments involving nitrogen, phosphorus, and potassium. Driskell, and Richer (3) obtained a correlation between tissue tests and visual symptoms of nitrogen, phosphorus, potassium, and mangnesium deficiency in corn. Cook, et al (2) concluded that green tissue testing should be considered as an additional aid in diagnosing plant nutritional disorders or in estimating the productive capacity of a soil. Forsee (4) found that tissue tests proved an invaluable tool for diagnosing deficiencies on a growing crop, especially in those cases where a representative soil sample would be difficult to obtain.

Interpretations of results from field experiments are often aided by tissue analysis. Scarseth (15) reported an example of interest on this phase of the subject. An experiment was conducted in Indiana to study various sources of phosphate for crop production. The plots were established at a time when the investigators believed that the soil could supply adequate quantities of potassium for normal growth. Results of tissue tests showed that potash was the first limiting factor and that the yields were a reflection of the available potash and not of the different phosphate sources.

Several investigators have used the technique of tissue testing to establish certain "critical levels" of elements in plants. Macy (14) proposed a theory of the relationship between the sufficiency of a nutrient and its percentage content in the plant as a measure of the quantitative mineral requirements of plants. His concept was based on the idea that there was a critical percentage of each nutrient in each kind of plant. Above this critical percentage was luxury consumption and below was poverty adjustment. Macy (14) stated that the poverty adjustment was nearly proportional to the deficiency until a minimum percentage was reached. Ulrich (18) reports that the critical level for each nutrient may be determined under conditions of known nutrient or fertilizer responses. He sampled the plant at regular intervals during the growing season and from the changes taking place in the nutrient concentration of the fertilized and unfertilized plants ascertained the approximate critical level for potassium in grapes. Tremblay and Baur (17) established standards to delineate the high, sufficient, low and deficient potassium contents of the leaves of the pea plant from the prebloom stage to the time of full bloom. Tentative limits were also established on the estimated concentration of phosphorus required in the pea plant during early growth stages. Gammon and Blue (8) were able to determine the minimum potassium requirements for optimum growth of white clover and Pangola grass pasture on the sandy soils of Florida. Plant analysis and observations from experiments conducted were used in establishing these values.

Fudge (6) reported that bronzing in grapefruit leaves could be prevented in seedy varieties when the magnesium requirement for fruit production could be satisfied without reducing the magnesium content of the leaves below about 0.12 percent. From his studies on the sodium and potassium requirements of Pangola grass, Gammon (7) concluded that sodium will substitute for approximately two-thirds of the potassium requirement without causing any appreciable reduction in growth. The data from tissue analysis and dry weights indicated that no further yield

increases in Pangola grass would be obtained when the sum of the sodium plus potassium in the oven-dry herbage totaled at least 20 milligrams per gram.

Forsee (4) used tissue tests as an aid in establishing soil testing procedures at the Everglades Experiment Station. The method consisted of extracting fresh plant material in a Waring blendor with 0.5 N acetic acid. An example taken from Forsee's (4) studies on celery fertilization illustrates how tissue testing was used in selecting a procedure for soil analysis for phosphorus.

Studies have been conducted on correlating yield, soil test, and tissue test data in an attempt to obtain information which would be of value in establishing a fertilizer program. A second example taken from a report by Forsee (5) is used to explain the procedure for the organic soils of the Everglades region.

Data compiled by correlating soil tests and tissue tests with plant growth and yields have been very useful. Such data furnish a basis for making fertilizer recommendations for crops on the basis of soil tests made before fertilizing and planting the crop. In addition, the tissue tests make it possible to offer suggestions as to corrective treatments to employ after the crop is planted. This is particularly true of crops fertilized in the row where a representative soil sample is difficult to obtain (4).

SUMMARY

Tissue testing has been of invaluable aid in locating causes of physiological disorders in plants. It has been used in the interpretation of the results from fertility experiments. Investigators have shown its value when used in combination with soil analysis for establishing a fertilizer program for various crops. The value of tissue testing as a guide in establishing suitable soil tests has also been shown.

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SOIL TESTING IN AN INSTRUCTIONAL PROGRAM IN SOILS

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In 1804, Theodore de Saussure of Switzerland directed attention of the scientific world to the fact that the ash ingredients of plants were taken from the soil and that they were, in the main, essential for plant growth. It is more than 100 years since Liebig advanced his mineral theory of plant nutrition and certain examinations of the soil were begun to determine the effects of fertilizers.

These discoveries opened new vistas to the agriculturally minded chemists of the day. It appeared to be a simple task indeed to analyze the plant to determine its mineral content, and the soil to measure its inorganic constituents and then putting the two together predict the abundance of plant growth. This simple procedure was followed for almost half a century until Whitney and Cameron in 1903 pointed out that while the then devised chemical methods were sufficiently accurate for determining the total amount of a given element present in the soil, they were not suitable for measuring the obviously small amounts of a single element involved in the production of a stated yield.

Others about this same time recognized the influences of the kind of crop, the physical structure of the soil, moisture relations, soil reaction and parent material on crop production and observed that these factors must be taken into account along with the soil analysis. We refer to this today as the "interpretation of the test."

Hilgard, writing in the Cyclopedia of American Agriculture in 1907, had this to say about soil analysis, and I quote, "It would thus seem that physico-chemical soil analysis, judiciously interpreted, is the quickest mode of obtaining definite information regarding the permanent value of soils, and, can probably serve for (measuring) the immediate producing capacity also." No doubt many have felt the same as Dr. Hilgard about soil testing, for despite the fact that soil analysis as a means of predicting fertilizer needs has been pitched about like a "hot potato" by the soil chemist, physicist, and biologist we still find the farmer and student standing at our door seeking assistance through this medium. To them it seems logical that such a test can be valuable in planning a fertilizer program.

The merits of such an assumption as pointed out above cannot be altogether denied, for Lyon, Buckman and Brady in their fifth edition of the Nature and Properties of Soils, after citing precautions to be observed in making the analysis, state that "rapid tests are an invaluable tool in making fertilizer recommendations. Moreover, these tests will become of even greater importance insofar as they are correlated with the results of field fertilizer experiments."

This brief introduction brings us to the position of evaluating soil testing in our instructional program. Such a program should include three broad objectives: first, a review of the early knowledge of plant

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nutrition and the development of our informational resources along lines of plant and soil analyses: secondly, an objective viewpoint should be taken with respect to total analysis of soils: and thirdly, a thorough evaluation of the so-called "quick test" or "rapid test" methods of qualitatively measuring plant nutrients in the soil.

The history of our early knowledge of plant nutrition and the development of soil chemistry is well known to us and when properly taught to the student obviously discloses the need for an analysis of the soil. The logical sequence to follow in instruction is to trace the progress of the total analysis, first by tedious gravimetrical procedures, then through the use of colorimetric measurements and, finally, to the employment of the spectrum in the flame photometer.

It goes without mention that a clear understanding of the procedures involved in the above analyses require a good background in mathematics, quantitative chemistry and physics. Only advanced undergraduate students majoring in soils or agricultural chemistry or graduate students in these fields have this essential background.

Many of the fields of Agriculture require only the very elementary courses in chemistry, with a larger group requiring such courses as general chemistry which includes, at least, an introduction to qualitative analysis. All of the areas of Agriculture here at Florida require at least our first course in soils with some in the first group mentioned above and practically all of the second group requiring a course in Soil Fertility.

With such facts confronting us, it was only logical that our instruction in soil analysis be held at a very elementary level in those courses accommodating the agricultural student at large. So for this purpose a series of qualitative tests were included in our elementary Soil Fertility laboratory. This gives the student an opportunity to get the "feel" of soil analysis and gives him an opportunity to "learn by doing."

Although there is a great deal to be desired with respect to absolute satisfaction in this type of laboratory, it offers several very worthwhile opportunities. It provides the instructor with an excellent tool for creating interest among the students. Those enrolled are encouraged to bring soil samples from the home farm for testing. This has a tremendous appeal to the student for he feels that he is bringing his own farm, garden or lawn right into the laboratory. It also provides an excellent opportunity for instruction in taking soil samples in a scientific manner for the very first laboratory exercise is a field trip to an area on the campus for instruction in soil sampling procedures. Other field trips include soil sampling from pastures, groves and field crops.

Finally, this type of laboratory provides a real opportunity for the instructor to evaluate for the student all phases of soil testing, such as, extracting solutions, interpreting the test, laboratory techniques and limitations of each test.

Our greatest need at the present time, so that our instruction may be as complete and up to date as possible, is more information from our Experiment Stations throughout the state with respect to correlation and field interpretation of soil tests. We sincerely believe progress is being made and that a real service will be rendered.

RELATION BETWEEN PHOSPHORUS RECOVERED BY PLANTS AND THAT REMOVED BY CHEMICAL EXTRACTANTS FROM FLORIDA SOILS

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Yield responses have shown that in many Florida soils part of the total soil phosphorus is held in the soil in a form unavailable to plants (8). This phenomenom is termed phosphorus fixation. The amount of phosphorus fixation varies between two extremes. It is of little importance in the sandy soils of Peninsular Florida (7) but on certain West Florida soils it may approach 100 percent (4, 6). It has also been shown, on soils that fix phosphorus, that residual fertilizer phosphorus is more available than virgin soil phosphorus (8), indicating that the fixed phosphorus is in a different form than the virgin soil phosphorus. These factors make it difficult to characterize the available phosphorus in soils chemically by the total phosphorus method.

The soil phosphorus available to plants may be evaluated by using an extractant that will remove phosphorus related to that available to plants. In order to make these studies, it is necessary to correlate the phosphorus removed by a particular extractant with yield data over a period of years. The phosphorus removed by the extractant when maximum yield is obtained is the basis for determining the phosphorus status of a particular soil. This approach is time consuming and limited to a small number of soil types because of cost. This paper suggests the possibility of using radioactive phosphorus as a tool to speed up correlation work.

Methods

The method outlined is particularly suited to greenhouse trials. When fertilizer phosphorus is mixed with all the soil in the pot the indicator plants will remove phosphorus from the fertilizer and soil in amounts relative to the availability of the phosphorus in each. When the applied phosphorus is tagged with P^{32} the percent phosphorus in the plants from the fertilizer is determined by the MacKenzie and Dean technique (5). After this value is obtained the phosphorus in the plant from the soil can be determined by difference. Assuming that the applied fertilizer phosphorus is available, the actual pounds of phosphorus in the soil that is available to plants can be calculated.

For instance, if 150 pounds of tagged P_2O_5 per acre is applied and 75 percent of the phosphorus in the plant is found to come from the fertilizer, the ratio of availability of fertilizer phosphorus to soil phosphorus is 75 to 25 or 3 to 1. By substituting 150 pounds P_2O_5 in the ratio as being available from the fertilizer, it follows that 50 pounds P_2O_5 must have been available in the soil. The 50 pounds of available phosphorus has been termed "A" value by Fried and Dean and has been

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shown to be in close agreement with the available phosphorus (2). The authors in this paper have attempted to correlate the available phosphorus determined in this way with the phosphorus removed by some common chemical extractants.

The percent recovery of known amounts of fertilizer phosphorus was available from greenhouse experiments designed to evaluate the effect of lime and/or phosphorus on the uptake of phosphorus from eight Florida soils (10, 11). Where there was a significant response to lime, the lime variable was eliminated by using soil samples and the percent recovery data from the treatment having the recommended pH level. Where there was no significant difference in phosphorus recovery for lime the soils and percent recovery data from the various lime levels were averaged.

Samples had been saved prior to the application of the tagged phosphorus and these were analyzed chemically to determine the total, strong Bray, weak Bray and Truog phosphorus. The total phosphorus was determined by the Parker and Fudge method (9). The strong Bray method utilized 0.03N NH_4F in 0.1N HCl as an extractant. It was used in the ratio of ten parts extractant to one part soil. The weak Bray method was similar to the strong Bray method except the HCl was 0.025N. The Truog phosphorus is the phosphorus removed with 0.002N H_2SO_4 buffered to pH 3 with $(NH_4)_2SO_4$ using 5 gms. of soil to 200 cc. of extractant. Phosphorus was determined colorimetrically in all methods. The Dickman and Bray method (1) was used for total, strong Bray and weak Bray methods and Parker's adaptation of Denige's method (9) was used for the Truog method.

Correlations were made on one soil under field conditions. The experiment was located on a Greenville fine sandy loam at West Florida Station. Soil samples were taken just before the corn was planted and tested as in the greenhouse experiment. The percent recovery was determined on the ear-leaf at tasselling time.

In both greenhouse and field experiments nitrogen, potash and minor element requirements were believed to be satisfied.

Since fixation of the applied fertilizer phosphorus would cause the correlations to be in error, precautions were taken to reduce the possibility of fixation. In the greenhouse, the crop used for the P^{32} data was harvested 20 to 30 days after the fertilizer was applied. A further check on the availability of the applied phosphorus was rates of applied phosphorus. When the percent in the plant from the fertilizer varied directly with rates it was an indication of total availability of applied phosphorus. If fixation was taking place, the percent in the plant from the fertilizer should vary inversely with rates, since more fixation would probably take place at the low rates. Fixation of applied phosphorus in the field was minimized since the residual supply was probably high enough to satisfy the fixation capacity.

RESULTS AND DISCUSSION

A general description of all the soils used in this study appears in Table 1.

Table 2 contains greenhouse correlation data on the first five soils described in Table 1. Of the five soils only the Red Bay fine sandy loam

TABLE 1.—Description of Soil Types Used for Phosphorus Correlations.*

Soil Type	Depth to Clay	Color		Drainage	Phosphorus Fixing Capacity	Origin
		Surface	Subsoil			
Scranton fine sand	42″ +	Dark gray to black	Brownish yellow to white	Somewhat poorly drained	Low	Non-calcareous sands
Red Bay fine sandy loam	14 to 24″	Dark brown or reddish brown	Red to yellowish red	Well drained	High	Non-calcareous sand and clay
Leon fine sand	42″ + (hardpan 14 to 30″)	Gray to dark gray	Light gray over dark brown hardpan	Somewhat poorly drained	Low	Non-calcareous sands
Lakeland fine sand	42″ +	Light gray to gray	Yellow	Well drained	Low	Non-calcareous sands
Arredondo fine sand	42″ +	Dark gray to brownish gray	Light reddish brown to reddish yellow	Well drained	Low	Sand and phosphatic limestone
Norfolk fine sand	14 to 24″	Dark gray	Yellow	Well drained	Medium	Non-calcareous sand and clay
Tifton fine sandy loam	14 to 24″	Dark gray to dark brown	Grayish yellow to reddish yellow	Well drained	High	Non-calcareous sand and clay
Greenville fine sandy loam	8 to 14″	Dark gray to dark brown	Red to yellowish red	Well drained	High	Non-calcareous sand and clay

* For a more complete description of these soils refer to Bulletin 524, Florida Agricultural Experiment Station (3).

has a high fixation capacity. It was collected near Quincy, Florida. The data in Table 2 indicate that of the three extractants tested the 0.002N H_2SO_4 buffered at pH 3 with $(NH_4)_2SO_4$ removed an amount more nearly comparable to the available phosphorus. Although the quantity removed was slightly low on the Red Bay fine sandy loam and Leon fine sand and slightly high on the Scranton fine sand, Lakeland fine sand and Arredondo fine sand the extractant was concluded to be satisfactory.

TABLE 2.—1951 Soil Test Correlations on Virgin and Cropped Florida Soils.

Soil Type	Years Cropped	Lbs./A. P_2O_5 in Soil				Available Phosphorus*			
		Total	Strong Bray	Weak Bray	Truog	Lbs./A. P_2O_5 Applied 100	200	400	Ave.
Scranton fs	Many	6870	3893	3023	354	456	514	530	500
Red Bay fsl	Virgin	6481	252	183	35	—	41	30	36
Leon fs	Virgin	243	57	69	38	27	17	5	18
Lakeland fs	Many	1772	1466	1328	92	—	133	180	156
Arredondo fs	Virgin	12297	5496	2656	184	376	356	433	388

* Determined using P^{32} and corresponds to "A" value (2).

Table 3 contains correlation data from a second greenhouse experiment using the Red Bay fine sandy loam, the Tifton fine sandy loam and the Norfolk loamy fine sand. Descriptions of these soils appear in Table 1. They are medium to high in their capacity to fix phosphorus. The Red Bay fine sandy loam is not the same soil as used in the previous experiment. It was collected at the West Florida Station near Jay. The number of years the soils were cropped is shown in Table 3. The Norfolk and Red Bay were virgin and the Tifton had been cropped one year at the beginning of the experiment. After removing two cuttings of oats and one of corn the pots were left for a second year and fertilized with a higher rate of tagged phosphorus. These soils were then considered one-year-old soils and correlation data were obtained as before. These data show that in general when the soils were virgin the Truog extractant was a better measure of available phosphorus than the two Bray extractants; however, when the soils had residual phosphorus, as in the first and second years' data for the Tifton and the second years' data for the Norfolk and Red Bay, the weak Bray extractant was a better measure of the available phosphorus.

Table 4 contains results from the field experiment on Greenville fine sandy loam. A description of the soil is found in Table 1. The main treatments shown in column 2 of Table 4 were made in 1951. They were subdivided into three plots which received 0, 30 and 60 pounds per acre of P_2O_5 annually. Soil samples were taken before the corn was planted from the subtreatment having no annual phosphorus application. The percent recovery of fertilizer phosphorus was obtained by tagging the 30-pound subtreatment and determining the phosphorus activity in the

corn leaf at tasselling time. Correlations were made with three extractants as in the previous experiments.

TABLE 3.—Soil Test Correlations on Virgin and Cropped Florida Soils.

Soil Type	Years Cropped	Lbs./A. P_2O_5 Applied	Lbs./A. P_2O_5 in Soil				Available Phosphorus*
			Total	Strong Bray	Weak Bray	Truog	
Norfolk lfs	0	50	465	183	156	37	58
	0	100	465	183	156	37	59
	1	100	564	229	189	49	90
	1	200	593	229	189	51	142
Red Bay fsl	0	50	687	34	23	11	5
	0	100	687	34	23	11	1
	1	125	716	97	30	29	46
	1	250	786	97	30	25	53
Tifton fsl	1	50	664	80	50	22	37
	1	100	664	80	50	22	37
	2	125	656	129	61	49	66
	2	250	725	138	73	48	77

* Determined using P^{32} and corresponds to "A" value (2).

The 0.03N NH_4F in 0.1N HCl removed phosphorus that correlated closely with the available phosphorus. The only discrepancy was obtained when the basic treatments were rock phosphate. This might be expected since the strong acid solution used in the test probably dissolved the rock phosphate particles present in the sample.

TABLE 4.—1953 Soil Test Correlations Using Residual Phosphorous Experiment.

No.	Treatment		Lbs./A. P_2O_5 in Soil				Available Phosphorus* 30 Lbs./A. P_2O_5 Applied
	P_2O_5 Broadcast 1951		Total	Strong Bray	Weak Bray	Truog	
	Lbs./A.	Source					
1	250	Super	854	327	191	89	381
2	500	250 pounds	1024	556	294	133	487
3	1000	from super	1260	900	553	282	780
4	2000	balance triple	2290	1482	1050	474	1004
5	1000	Rock	1756	982	225	479	759
6	2000	Rock	2778	1784	206	806	702

* Determined using P^{32} and corresponds to "A" value (2).

CONCLUSION

A method has been presented by which chemical extractants can be evaluated as to their effectiveness in giving a quantitative measure of available phosphorus. Using this method, correlations were made on nine Florida soils.

The Truog extractant, 0.002N H_2SO_4 buffered at pH 3 with $(NH_4)_2SO_4$, most nearly characterized the available phosphorus in soils with low phosphorus fixation capacity.

For the soils with high phosphorus fixing capacity, the Truog extractant was satisfactory on virgin soil, but when residual phosphorus was present it did not remove sufficient phosphorus. When the residual phosphorus was in the order of 50 pounds P_2O_5 per acre the weak Bray extractant, 0.03N NH_4F in 0.025N HCl, was satisfactory. When the residual phosphorus was over 200 pounds P_2O_5 per acre the strong Bray extractant, 0.03N NH_4F in 0.1N HCl, gave a better measure of the available phosphorus. It is suggested that in soils that fix phosphorus, residual phosphorus is held in an anion exchangeable form which requires an anion in the extractant to remove it.

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FACTORS AFFECTING CALCIUM UTILIZATION BY PLANTS

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Florida soils may contain between 200 to 20,000 pounds of calcium per acre-6-inches. The amount of calcium removed by crops usually varies from 1 to 100 pounds per acre. Thus it would appear that the supply of calcium should very seldom be a factor in limiting plant growth. However, recent research emphasizes the point that calcium utilization by the plant may be affected by a number of factors which seem to be only slightly influenced by the calcium supply in the soil.

Dusting the peanut plant with gypsum at the early fruiting stage is an old practice (2). Yields will be increased by utilizing this practice if the available calcium is low in the top 2 or 3 inches of soil. The young fruit must get calcium from the soil which surrounds it before it can become a mature fruit because only a limited amount of the calcium taken up by the root of the plant ever reaches the fruit.

"Topple", a disease of gladiolus occurring after the spikes have been cut, has been reported by Fink (4) to be associated with calcium supply. Because the well known "topple" disease of tulips has been corrected with calcium supplements, similar treatments were tried with gladiolus. Soil applications were only slightly effective as a control. When spikes were sprayed with a 2 percent calcium nitrate solution, only 18.7 percent of the flowers toppled, whereas 67 percent of those not sprayed toppled. All treatments were applied 2 weeks before bloom.

Blossom-end rot, a physiological disease of tomato, has sometimes been associated with calcium nutrition. Evans and Troxler (3) were able to obtain limited control by calcium application when applied to the soil and also when used as a foliar spray at weekly intervals. However, in greenhouse studies, when fruits were injected with calcium gluconate, blossom-end rot was completely controlled. The normal fruit contained significantly more calcium than diseased fruit.

A physiological disorder of celery, known as blackheart, has been completely controlled by applications of a calcium solution directly into the heart of the plant (6). Experimental data indicate that most celery soils usually contain adequate amounts of calcium but blackhearted tissue from plants grown on these soils was found to contain less calcium than similar tissue from healthy plants. Plants grown in greenhouse nutrient cultures developed blackheart regardless of the amount of calcium in the culture solution. However, the severity of the symptoms varied inversely as the level of calcium maintained in the solution. On the other hand, in no case did a greenhouse plant grown in similar solutions develop blackheart as long as a calcium solution was applied to the heart of the plant twice weekly.

The results of the experimental evidence indicate that certain plants or specifically plant parts cannot obtain sufficient calcium from the roots for normal metabolism.

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In a study of the various aspects of calcium nutrition, it is logical to consider factors which affect calcium availability in the soil, absorption by the root, and translocation and assimilation of calcium within the plant. It is evident that calcium supply is an important independent factor which need not be discussed further at this time.

In comparing different substrates and the growth of different plants in relation to cation uptake, Marshall and Upchurch (9) concluded that three controlling factors must be taken into consideration:

(1) The mean free energy change of the reaction in which nutrient ions are exchanged for hydrogen ions.

(2) The activity of the cation under consideration in the nutrient medium.

(3) The activity of the hydrogen ion.

The mean free energy change of a reaction is the algebraic sum of the free bonding energies involved. Let us consider a particular reaction:

$$\text{Colloid Ca} + \text{Root H} \rightleftharpoons \text{Colloid H} + \text{Root Ca}.$$

There are four cationic free bonding energies involved in the above equation. The resultant free energy is the driving force under the given conditions.

Indications are that free energy changes in cation exchange reactions are of great importance in the uptake of cations by plant roots. The effects of some differential bonding energies of roots can best be illustrated by results of recent experiments conducted in Arkansas by McLean and associates (10). They found that the ratio of the mean free bonding energy for calcium at 100 percent saturation to the mean free bonding energy of potassium at 100 percent saturation was 1.0 for Reed canary grass, 1.2 for red top, 2.0 for Arkwin oats, and 3.3 for buckwheat. This means that buckwheat bonded calcium on a molar basis 3.3 times as strongly as potassium. This in turn is considered a very important factor in the ability of buckwheat to utilize rock phosphate. This concept is also a means of explaining the ability of the grass in a grass-legume pasture mixture to obtain potassium at the expense of the legume.

Such an approach also helps to explain many puzzling results in the literature in which comparisons have been made between colloidal media and true solutions or between different colloidal media.

The activity of the cation under consideration and the hydrogen on the root are important individual factors in the overall exchange. The ease of release of an ion from the soil colloid is expressed by its activity coefficient which is determined by the radius, valence, hydration and ionic strength of the ion as well as the type of colloid and the degree of saturation of the particular ion (12). The lower the activity of a specific ion as related to the complimentary ions, the more difficult that ion is to replace. The greater this difference between coefficients, the more the exchange of the ion will be influenced by varying degree of saturation. Relative activity coefficients of some of the common cations are as follows: $Na > K > Mg > Ca$. Many experiments indicate sodium has an adverse effect upon the uptake of cations with lower activity coefficients. Such an effect would be the greatest between sodium and calcium. For purposes of illustration let us consider blackheart of celery which is often associated with high soluble salts in the soil. Generally sodium salts or a

combination of sodium and potassium salts comprise a large portion of the total salts in high salt areas. Celery plants growing in such areas are found to contain less calcium than plants growing in areas where the salt concentration is lower (6).

The measurement of the activity of the hydrogen ion as the exchange cation on the root is often obscured by metabolic processes which produce weak acids (9). Such fluctuating activities are difficult to measure, but are recognized as important in the uptake of cations by the plant.

In order to better understand this particular calcium problem, the factors usually associated with the deficiency should be considered. For example, blackheart of celery is associated not only with high soluble salts but also with unbalanced moisture, over-fertilization and relatively high temperatures. Blossom-end rot of tomato is also associated with many similar conditions. The deficiency is most apparent in all plants here considered (peanut, gladiolus, tomato and celery) during periods of rapid growth. It appears that rapid growth makes the plant more sensitive to the effects of contributing factors because per unit of time, the requirement for calcium is further extended. The calcium deficiency may be of a temporary nature, or more or less permanent depending on the associated conditions.

Let us now consider the physiological problems of translocation and assimilation of calcium in the plant. It is well known that calcium is only slightly translocated, if at all, from older to younger tissue. In celery, for instance, older leaves may contain 3 to 4 percent calcium (oven dry basis) whereas the young heart leaves of the same plant will contain only 0.3 to 0.4 percent. Such plants may blackheart because insufficient calcium is available to the young, rapidly growing tissue (6).

The effect of weak acids, metabolized by the plants, on the activity of the hydrogen ions on the root has already been mentioned. Experimental evidence indicates that blackheart of celery (6) and blossom-end rot of tomato (3) may be associated with conditions causing an abnormal metabolism which produces excessive amounts of certain organic acids. When a 2 percent solution of citric acid was injected into a tomato fruit, a breakdown of the tissue similar to blossom-end rot was produced (3). When a .05 molar solution of sodium citrate or oxalate was sprayed into the heart of the celery plant, a breakdown of the tissue similar to blackheart was produced (6). Calcium oxalate is very insoluble while the citrate ion may act as a calcium chelater. Chelated calcium would generally be unavailable for translocation or assimilation. Thus the calcium may be immobilized in the process of translocation before it reaches the point where it can be assimilated and utilized for plant growth. This hypothesis does not exclude the possibility of excessive quantities of certain organic acids being produced in a localized area, thus causing a localized physiological disorder.

Some factors such as excessive nitrate nitrogen are known to increase the amounts of organic acids metabolized by the plant (8). Other factors such as light affect the metabolism of particular acids. Darkness favors the production of citric acid (13). Light may also have an effect on calcium uptake. It was observed by Bennedict (1) that ultra voilet rays between 2900 and 3100 Å caused an increase in the percentage of calcium in all plants that he examined. Pierce and Appleman (11) state that the content of insoluble oxalates and insoluble calcium in 12 dif-

ferent plant species was highly correlated. Gilbert et al (7) found that oxalic acid formation in tung leaves was related directly to nitrate concentration and uptake as well as to the supply and uptake of calcium.

Temperature is a factor known to be associated with the problem and would affect rate of growth. It would indirectly or perhaps directly affect calcium uptake and assimilation also. Freeland (5) has reported that high transpiration as associated with high temperatures caused bean and corn plants to take up relatively more potassium and less calcium. Unbalanced moisture is a condition which could radically change the balance of cations in the soil and also upset plant metabolism in a number of ways. There are perhaps many other known and unknown factors which, with those already mentioned, are interrelated and act interdependently. The summation total could result in observed or unobserved effects on growth.

SUMMARY

Considering all the evidence, it seems apparent that calcium utilization by plants is influenced by factors which affect the movement of calcium anywhere from substrate to the point of assimilation in the plant. The effect of such factors is intensified under modern agricultural practices directed toward increasing yields by means of more rapid plant growth. The importance of the problem becomes more apparent, as more physiological disorders are found to be associated with calcium.

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YIELDS AND CHEMICAL COMPOSITION OF CLOVER-PANGOLAGRASS MIXTURES GROWN ON IMMOKALEE FINE SAND, AS INFLUENCED BY LIMING AND APPLICATION OF SOLUBLE AND INSOLUBLE SOURCES OF PHOSPHATE AND POTASH

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The rapid growth of the Florida cattle industry and the successful growth of legumes on flatwood sandy soils have stimulated research in the establishment and maintenance of improved clover-grass pastures. An integral part of the overall study concerns the use of soil amendments and fertilizers in a manner which will provide a high grade feed economically.

The clover-pangolagrass plots discussed in this paper, were established to accumulate additional information on legume-grass mixtures with respect to yields and chemical composition along with some estimates of the cost of establishment and maintenance. No attempt has been made to use supplemental nitrogen fertilizers. It was not intended to produce maximum yields of forage but rather to determine some of the unsolved factors involved with maximum legume growth at minimum cost. If soil moisture conditions are favorable legumes are the most economical means of obtaining high quality winter and spring forage, since they produce 50 to 100 pounds of nitrogen per acre per season in the form of protein (13). Blaser and coworkers (2) compared the effects of clover-grass pastures versus unfertilized and fertilized grass pastures on the pounds of beef gained per acre. Their results clearly indicated the desirability of legume-grass pastures for the increased production of beef.

EXPERIMENTAL

General

A field experiment of split-plot design was begun on Immokalee fine sand in August 1952 to determine the effects of various soil amendments and fertilizer materials on clover-pangolagrass yields and chemical composition. The original soil pH averaged 4.7 and the average moisture equivalent was 6.1.

The soil amendments,[1] dolomite, basic slag, lime hydrate, and gypsum[2] at 3,600, 3,400, 3,600, and 4,000 pounds per acre, respectively, constituted

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[1] Dolomite used: $CaCO_3$-49%, $MgCO_3$-36%, 60 and 80% passing 60 and 30 mesh sieves, respectively. Basic slag used: Tenn. ground open hearth, containing P_2O_5-8%, CaO-40%, MgO-5%, MnO-3%, Zn-trace, Fe-greater than 1%, Si-greater than 1%, Al-1%, Na-0.1%, Mo-0.006%, and Cu-0.006%, neutralizing power 80% with 70% passing through a 100 mesh sieve. Lime hydrate used: 95% passing through a 325 mesh sieve. Gypsum used: land plaster.

[2] Gypsum, although not classified as a soil amendment will be considered as one in this discussion.

the main plots (15 x 60 feet). Subplots (15 x 15 feet) received the following treatments: 1. Two tons of rock potash and one ton rock phosphate per acre; 2. Four tons of rock potash and two tons rock phosphate[3] per acre; 3. Muriate of potash plus superphosphate when necessary, and 4. Muriate of potash at one-half the rate applied in 3 plus a molecular equivalent of soda (Na_2O), as NaCl (table salt): superphosphate was applied at the same rates as No. 3. Each main plot treatment was replicated four times, and each subplot treatment was superimposed upon each main plot treatment.

Lime hydrate is a faster reacting material than high calcic limestone and normally contains somewhat less Mg but its characteristic action in the soil over a period of time should tend to approach that of high calcic limestone. The gypsum plots were included to provide calcium without materially affecting the soil acidity, in order to determine whether or not the acid soil conditions might appreciably increase the availability of K from rock potash.

Rock phosphate has been used successfully to supply P to clover (6, 8, 9), and was used in this test to provide a cheap source of phosphorus. Much advertising recently has been made with respect to the use of rock potash for various crops in Florida. This ground granite rock had been used during the early 1900's and recently Swanback indicated response of tobacco plants to rock potash (12). The large applications of this material were used because its relative availability is small.

Methods of Procedure[4]

Amendments and rock sources of P and K were applied with a three foot Gandy distributor, and soluble sources of K and Na were applied by hand. A three-foot sickle bar mower was used as an aid in obtaining yields. Usual methods for obtaining yield data and percent dry matter were employed. Sample drying temperatures were either 75-80 or 100 degrees centigrade. All samples for major element determinations were ground through a Wiley mill and a nylon slip-roll puverizer was used for preparing samples for trace element analyses.

Methods for plant analyses for K, Ca, Na, P, Mn, and Fe were similar to those outlined by Toth, et al. (14). Magnesium was estimated by the Drosdoff and Nearpass method (3) while Cu was determined by a modification of the Sandell procedure (11). Nitric-perchloric acid wet digestions were used for all samples. The A.O.A.C. method was used for crude protein determinations (7).

Tissue tests were made by extracting 1 gram oven dry ground samples with 0.5 *N* acetic acid in a Waring blendor and soil tests were made according to procedures outlined by Forsee.[5]

Values presented in Tables 1 through 5 are average values with respect to the four main treatments and the four subtreatments.

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[3] Rock phosphate used: finely ground, total P_2O_5-33%, readily available P_2O_5-3%. Rock potash used: coarse ground, 9% K_2O.

[4] We wish to thank Mr. J. W. Batista, Laboratory Assistant, for making most of the chemical determinations.

[5] Mimeographed paper, Soil Testing, Rapid Laboratory Methods. W. T. Forsee, Jr., Chemist in Charge, Everglades Experiment Station.

TABLE 1.—The Effects of Soil Amendments and Fertilizers on Ca, Mg, Na, K, and P Contents, and pH Values of 0 to 6 Inch Soil Samples Taken 12/13/52.

Treatment*	pH	Ca	Mg	Na	K	P
		Lbs./A.	Lbs./A.	Lbs./A.	Lbs./A.	Lbs./A.
1. D.	5.80	700	260	35	20	10 5
2. H.L.	6.00	965	70	35	20	8.0
3. B.S.	5.50	670	100	35	25	22.0
4. G.	4.35	565	25	35	20	16.0
L.S.D. .05	0.60	145	45	N.S.	N.S.	5.0
L.S.D. .01	0.85	210	60			7.0
a. 2RK-1RP	5.40	755	115	35	25	15.5
b. 4RK-2RP	5.45	815	115	35	20	18.5
c. K	5.30	665	110	30	20	11.0
d. K-Na	5.25	670	115	35	20	11 5

* D. = dolomite, H.L. = hydrated lime, B.S. = basic slag, G. = gypsum, 2RK-1RP = 2 tons rock potash-1 ton rock phosphate, 4RK-2RP = 4 tons rock potash-2 tons rock phosphate, K = 80 pounds K_2O, and K-Na = 40 pounds K_2O-40 pounds Na_2O.

Applications of soil amendments and the insoluble sources of fertilizers were completed August 11, 1952, and pangolagrass sprigs were disked into the soil. Five hundred pounds per acre of 4-8-8 containing 2 percent MgO, 0.4 percent MnO, 0.3 percent CuO, 0.2 percent FeO, and 0.15 percent B_2O_3 were then applied. The trace elements and Mg, except for B as borax, were derived from sulfates. Kenland Red and Louisiana White Dutch clovers were seeded November 10 at 6 and 2¼ pounds an acre, respectively. To remedy the uneven stand of clover, the area was mowed and clippings removed on November 21 and nitrate of potash at 150 pounds per acre was applied broadcast to all plots on October 17. Initial soluble K and K-Na[6] applications were made January 31. Fertilization rates were selected on the basis of soil tests made on samples collected December 12, 1952.

Harvesting, soil analyses, rainfall, and fertilization information are listed as follows:

1. 12-12-52—Soil samples taken.
2. 1-31-53—Fertilized with 80 lbs. K_2O (as KCl) and 40 lbs. each of K_2O and Na_2O (as NaCl) per acre.
3. 3-23-53—Harvested all plots and separated clover and grass.
4. 5-21-53—Harvested all plots.
5. 6-2-53—Fertilized at same rates as January 31 fertilization (15.64 inches of rainfall from 1-31-53).
6. 7-10-53—Harvested all plots and soil samples taken (13.50 inches rainfall from 6-2-53).
7. 9-22-53—Harvested all plots (44.15 inches of rainfall from 6-2-53).

[6] Throughout this paper the K treatments refer to muriate of potash applications while K-Na treatments refer to one-half muriate of potash and one-half NaCl.

RESULTS AND DISCUSSION

Results of soil analyses, 12-13-52 are reported in Table 1. They indicate that soil pH values for all but the gypsum treatment were the same even though the Ca and Mg contents for hydrated lime and dolomite, respectively, were significantly greater. Water soluble soil P contents were increased by lower pH values and the additional 8 percent P supplied by the basic slag. The increased Ca from the rock source treatments is probably due to the release of Ca from rock phosphate. Addition of rock phosphate resulted in increased available P, while the release of K by rock potash was not effected even at low pH values. Ratios for soil Ca:Mg due to the application of various amendments ranged from 3:1 to 20:1. Bear, et al., (1), and others (10) indicate that continued use of high calcium liming materials, particularly where large quantities of potash fertilizers are used, would increase the possibilities of Mg deficiencies since clovers and grasses normally have Ca:Mg ratios of no greater than 2:1.

In Table 2 are data on the Ca, Mg, Na, K, and P contents, as well as dry weight yields for clover and pangolagrass. The majority of the clover harvested at this time was red clover. Plant ratios of Ca:Mg contents range from 2:1 to 5:1 and 1:1 to 3:1 for clover and grass, respectively. The Ca and Mg contents in the soil are generally reflected in the plants. This phenomenon generally holds true for Na, K and P. The Ca and Mg contents generally were less where the soluble fertilizers had been added. This is particularly true for the clover and indicates the repressive effect of K on the absorption of divalent cations. The Na contents of both clover and grass were reduced by the all K fertilization. Clover receiving K-Na contained smaller quantities of K than clover receiving only K, but no differences were noted for pangolagrass.

All amendments except gypsum resulted in equal clover and grass yields. The effects of soluble K and Na on clover yields are quite evident. Both treatments resulted in increased yields that were highly significant compared to yields obtained on the insoluble P and K treated clover. Clover from the insoluble P and K treatments revealed typical K deficiency symptoms at harvest time.

Gammon and others (4, 5, 6) have studied the Na and K relationships in pangolagrass and clover. They found that with an adequate supply of all other nutrients, both clover and pangolagrass produced maximum growth when soluble K in the plant is 2 percent or higher. Observations indicate that normal growth of clover will proceed at lower K contents, with K deficiency symptoms appearing when the K content in the clover approaches 1 percent. Futhermore, in preliminary tests, they indicated that no appreciable quantity of Na can be used to replace the K requirements of clovers. Although, from these tests it is impossible to state definitely that maximum clover growth occurred on the all K treated plots (K content 1.77 percent), it is possible to say that equal yields of clover, containing 1.23 percent K, were obtained as a result of the K-Na treatments. Grass yields were not affected by K treatment although K contents varied from about 1.2 to 1.5 percent.

The P contents of both clover and grass are high, and a correlation seems to exist between soluble soil P (Table 1) and forage contents. Sulfur, iron and manganese contents of clover and grass, and copper

TABLE 2.—The Effects of Applications of Soil Amendments and Fertilizers on Dry Weight Yields, and Ca, Mg, Na, K, and P Contents of Clover and Pangolagrass and Correlation Coefficients Between Species for Individual Elements (Harvested 3/23/53).

Treatment*	Ca-%		Mg-%		Na-%		K-%		P-%		Yields—Lbs./A.	
	Clover	Grass	Clover	Grass	Clover	Grass	Clover	Grass	Clover	Grass	Clover	Grass
1. D.	1.65	0.24	0.82	0.23	0.15	0.60	1.23	1.14	0.32	0.35	825	575
2. H.L.	2.16	0.30	0 38	0.16	0.14	0.51	1.29	1.30	0.27	0 26	650	425
3. B.S.	1.78	0.26	0.53	0.19	0.15	0.70	1.21	1.42	0 42	0.50	925	675
4. G.	1.76	0.32	0.36	0.11	0 15	0.55	1 15	1.26	0.42	0.45	200	225
L.S.D. .05	0.26	N.S.	0.11	0.02	N.S.	N.S.	N.S.	N.S.	0.04	0.05	375	275
L.S.D. .01	0 37		0.16	0 03					0.05	0.07	550	N.S.
a. 2RK-1RP	1.91	0.28	0.62	0.19	0.16	0.60	0.99	1.22	0.38	0.42	450	400
b. 4RK-2RP	2.00	0.26	0.57	0.17	0 19	0.69	0 93	1.19	0.41	0.40	475	500
c. K	1.68	0.29	0.38	0.16	0.08	0.49	1.77	1.58	0.32	0.39	875	525
d. K-Na	1.77	0.28	0 52	0.17	0.15	0.66	1.23	1.43	0.32	0.37	800	525
L.S.D. .05	0.20	N.S.	0.16	0.02	0.04	0.09	0.30	0 26	0.04	N.S.	250	N.S.
L.S.D. .01	N.S.		N S.	N.S.	0.05	N.S.	0.40	0.35	0.05		325	
Corr. Coeff. (r)**	0.16		0.48		0.45		0.78		0.69			

* See footnote in Table 1 for treatment identification.

** For significance at 5 and 1% levels, (r) must be greater than 0.50 and 0.63, respectively.

contents of grass are presented in Table 3. The effects of basic slag and gypsum treatments on resultant increased Fe and particularly Mn contents were evident. Even so, the lowest of these contents should be sufficiently high for maximum forage and animal growth. Increased Cu contents of pangolagrass was associated with the soluble treatments.

TABLE 3.—The S, Fe, and Mn Contents of Clover and Pangolagrass, and the Cu Contents of Pangolagrass Harvested 3/23/53, as Affected by Soil Amendments and Fertilizer Applications.

Treatment*	S-%		Fe-ppm		Mn-ppm		Cu-ppm
	Clover	Grass	Clover	Grass	Clover	Grass	Grass
1. D.	0.15	0.16	84	43	57	77	5.6
2. H.L.	0 17	0.15	78	47	71	58	4.8
3. B.S.	0.22	0.17	99	55	146	285	5.7
4. G.	0.31	0.21	91	56	159	162	4.0
L.S.D. .05	0.07	N.S.	9.5	5.0	31	51	N.S.
L.S.D. .01	0.10		14.0	7.5	44	73	
a. 2RK-1RP	0.22	0.17	96	48	123	138	4.3
b. 4RK-2RP	0.20	0.17	90	49	106	125	4 8
c. K	0.23	0.16	85	54	112	176	5.3
d. K-Na	0.21	0.18	82	56	101	143	5.7
L.S.D. .05	N.S.	N.S.	N.S.	N.S.	N.S.	32	0.5
L.S.D. .01						N.S.	0.7
Corr. Coeff. (r)**	0.88		0.15		0.74		

* See footnote in Table 1 for treatment identification.

** For significance at 5 and 1% levels, (r) must be greater than 0.50 and 0.63, respectively.

Highly significant correlations for K, P, S, and Mn contents existed between clover and grass. Clover and grass contents of other elements were not correlated.

Soil, tissue, and protein analyses of samples taken July 7, are reported in Table 4. At that time the majority of forage was pangolagrass. Data dealing with soil analyses indicate little change in pH compared to soil analyses from previous samples (see Table 1). Although soil Ca contents were about 200 to 300 pounds less than the samples taken in July, P contents were nearly the same. Magnesium contents appear to be larger but actually this was a result of determining Mg by the flame photometer, which normally gives higher results than the thiazole yellow method.

The extraction of ground, dried plant material with 0.5 *N* acetic acid, for the determination of K, Na, and P seemed to result in satisfactory relative values even though soil and plant K contents were not correlated.

Protein contents were adversely affected by applications of gypsum compared to forage from the other soil amendment plots. The protein contents of these samples (mainly pangolagrass) were largely affected

TABLE 4.—The Effects of Soil Amendments, Phosphate, Potash, and Soda on Soil pH, Soil and Plant Contents of Ca, Mg, K, Na, and P, Plant Protein Contents and Dry Weight Yields, and Correlation Coefficients Between Soil and Tissue Analyses (7/10/53).

Treatment*	pH	Ca		Mg		K		Na		P		Protein Yields	
		Soil	Plant	Soil	Plant	Soil	Plant	Soil	Plant	Soil	Plant	Plant	
		Lbs./A.	%	Lbs./A.	%	Lbs./A.	%	Lbs./A.	%	Lbs./A.	%	%	Lbs./A.
1. D.	5.80	470	.09	300	.31	27	1.20	35	.49	10	.24	5.10	2,550
2. H.L.	6.00	800	.16	110	.27	26	1.25	31	.45	6	.17	5.22	2,075
3. B.S.	5.30	450	.09	130	.23	28	1.07	31	.57	20	.30	4.59	2,800
4. G.	4.65	315	.09	40	.15	34	1.09	18	.40	22	.31	3.42	1,825
L.S.D. .05	0.45	40	.03	30	.05	N.S.	N.S.	N.S.	N.S.	6	.06	0.90	450
L.S.D. .01	0.65	60	.05	40	.07					8	.08	1.30	N.S.
a. 2RK-1RP	5.50	590	.09	160	.22	24	0.97	29	.52	15	.27	4.00	2,350
b. 4RK-2RP	5.50	595	.09	160	.23	23	0.86	30	.60	21	.30	4.20	2,350
c. K	5.35	415	.13	120	.27	40	1.53	24	.33	12	.23	5.51	2,225
d. K-Na	5.40	435	.12	135	.24	28	1.28	32	.46	11	.23	4.63	2,350
L.S.D. .05	N.S.	79	.02	29	N.S.	5.0	0.06	5.0	.09	5	.04	0.74	N.S.
L.S.D. .01		104	.03	N.S.		6.5	0.08	6.5	.12	7	.05	0.99	
Corr. Coeff. (r)**		0.45		0.69		0.46		0.67		0.91			

* See footnote in Table 1 for treatment identification.

** Coefficients greater than 0.50 and 0.63 are significant at the 5 and 1 percent levels respectively.

by the preceding quantity and quality of clover produced. This association may be compared more readily by noting the clover yields in Table 1 and the protein contents in Table 4. By multiplying the percent protein by the yield of clover in pounds per acre, the association is even more evident. Values in pounds per acre of protein produced (percent protein times yields) for treatments 1 through d are approximately 130, 108, 128, 63, 94, 99, 124, and 109, respectively.

Total dry weight yield data for four separate harvests and the grand totals are recorded in Table 5. Examination of these data with respect to the effects of soil amendments indicated that increasing production of forage resulted from the basic slag treatment compared to the other amendments. Forage grown on basic slag treated plots produced more dry matter than that produced on gypsum treated plots on March 23, and May 21; more than hydrated lime and gypsum on July 7, and more than dolomite, hydrated lime, and gypsum on September 22. This is a good indication of plant response to some secondary or trace element contained in the basic slag. It should be remembered that only an initial overall application of Mg, Cu, Mn, Fe, and B was made to the plots. It is doubtful whether this increased growth would have occurred with the addition of a complete trace and secondary element mixture to all of the plots at the time of the initial fertilization with soluble potash and soda (1-31-53).

TABLE 5.—Dry Weight Yields of Four Harvests, and Totals, as Affected by Applications of Various Amendments and Phosphate, Potash, and Soda.

Treatment*	3/23	5/21	7/10	9/11	Total
	Lbs./A.	Lbs./A.	Lbs./A.	Lbs./A.	Lbs./A.
1. D.	1,400	1,250	2,550	1,750	6,950
2. H.L.	1,075	1,000	2,050	1,650	5,775
3. B.S.	1,600	1,400	2,800	2,050	7,850
4. G.	425	450	1,800	1,300	3,975
L.S D. .05	725	500	550	150	——
L.S.D. .01	N.S.	N.S.	N.S.	N.S.	——
a. 2RK-1RP	850	1,000	2,350	1,800	6,000
b. 4RK-2RP	975	1,200	2,350	1,800	6,325
c. K	1,400	1,100	2,225	1,550	6,275
d. K-Na	1,325	900	2,350	1,600	6,175
L.S.D. .05	400	N.S.	N.S.	N.S.	——

* See footnote in Table 1 for treatment identification.

Data from Table 5 also indicate that clover plus grass dry weight yields between various K_2O-P_2O_5 treated plots were not significant (except for March 23). It should be remembered, however, that clover yields were significantly increased on March 23 by the use of K and K-Na (Table 2). This effect was visually apparent with decreasing magnitude from that time until clover growth was almost non-existant (July). Even

at this time, as mentioned previously, protein contents of the forage tended to be higher for plants receiving soluble K and K-Na (Table 4). From these observations, it may be stated that on a protein content times dry weight basis, the forage produced on the soluble treated plots was much greater than forage grown on the insoluble treated plots.

In order to obtain some general understanding of the increased beef per acre that must be produced on improved clover-grass pastures to secure a satisfactory monetary return from the fertilization investment, some approximate cost estimates were made. These estimates were based on the cost of fertilizer materials for the lower east coast of Florida. Distribution costs were based on a figure of one dollar an acre for soluble fertilizers and about three, three, four, and four dollars an acre per ton for dolomite limestone, high-calcic limestone, basic slag, and rock phosphate, respectively.[7] High-calcic limestone has been substituted for lime hydrate because it is much less expensive.

TABLE 6.—The Effects of Pasture Establishment and Maintenance on the Approximate Cost per Acre for Fertilizers, Soil Amendments, and Distributor Costs.

Treatment*	Complete Fertilizer**	Individual†	Distributor Costs	Total Costs
	Dollars	Dollars	Dollars	Dollars
1. D.	15	20	1	36
2. H.L.‡	15	16	1	32
3. B.S.	15	52	1	68
a. 2RK-1RP	15	40-14	1	70
b. 4RK-2RP	15	80-28	1	124
c. K	15	11	4	30
d. K-Na	15	9	4	28

* See footnote in Table 1 for treatment identification.

** Initial application of 500 pounds 4-8-8 plus secondary and trace elements.

† Three applications of 80 lbs. K_2O (as muriate of potash) and 40 lbs. K_2O-40 lbs. Na_2O (as table salt), and initial applications of soil amendments and rock potash; distribution costs for soil amendments and rock sources are included in this figure.

‡ Calculated on a basis of hi-calcic limestone.

Estimates reported in Table 6 are based on the costs per acre of the fertilizer materials used during the initial year of this experiment. Gypsum values are omitted because this treatment was obviously inferior with respect to the production of quantity and quality forage. Soil amendment costs are based on two-ton applications per acre for the sake of convenience. The cost of rock potash, which liberates little or no K, is prohibitive

[7] Approximate rate of commercial spreader service.

when compared to soluble K or K-Na fertilizers. Muriate of potash (60%) and NaCl cost about $2.80 and $1.40 per hundred pounds, respectively.

TABLE 7.—The Total Cost per Acre of Fertilization for the First, Second and Total Five Initial Years.

Treatment	1st Year	2nd Year	Total 1st 5 Years
	Dollars	Dollars	Dollars
1c. Dolomite-80 lbs. K_2O	55	16	119
2c. Hi-calcic-80 lbs. K_2O	51	16	115
3c. Basic slag-80 lbs. K_2O	87	16	151
1d. Dolomite-40 lbs. K_2O-40 lbs. Na_2O	52	14	108
2d. Hi-calcic-40 lbs. K_2O-40 lbs. Na_2O	48	14	104
3d. Basis slag-40 lbs. K_2O-40 lbs. Na_2O	84	14	140

In Table 7 are recorded data which indicate the cost of adding soil amendments and muriate of potash and NaCl the initial year, the second year, and the total five year period. Included in the initial years estimate was one ton of rock phosphate per acre, soil amendments at a rate of two tons per acre, four applications of K or K-Na treatments, two dollars an acre for trace or secondary elements, and distribution expenses. On each succeeding year the cost is based on three applications of K or K-Na, two dollars for trace elements, and distribution charges. These rates of fertilization naturally would be revised according to soil factors.

About 9 percent saving is realized on the basis of five year total if Na-K rather than all K is used. It must be remembered, however, that preliminary results indicated lower protein contents associated with Na-K treatment. On the same basis the use of basic slag would increase costs about 30 percent compared to dolomitic or high-calcic limestone. More than 1,000 pounds of ten cent beef (during the five-year period) must be produced (above that produced on native unimproved land) using any of the programs in Table 7, before any profit is made from the pasture fertilization program.

Blaser and co-workers (2) have shown by tests carried out over a four-year period that fertilization of clover-carpetgrass pastures resulted in a yearly beef gain of about 600 pounds of beef an acre, compared to gains of 150 and 75 pounds per acre made by grazing fertilized and unfertilized carpetgrass, respectively. These results suggest the possibility of large monetary returns by using the proper fertilization program for clover growth. The desirability of growing a winter legume cannot be over-emphasized, particularly with respect to the cost of producing quality forage on sandy soils of inherently low natural fertility.

SUMMARY

1. The use of rock potash to supply K to clover in these tests was of negligible value, compared to soluble potash. The cost makes its use prohibitive for clover production.

2. Rock phosphate at one or two tons per acre resulted in increased water soluble soil P and increased clover and grass P contents, although P values resulting from the application of 500 lbs. 4-8-8 were sufficiently high during the initial year.

3. Dry weight production of clover was equal whether K or K-Na treatments were used. Chemical analyses of clover and pongolagrass, as a result of these respective treatments, indicated percent K contents of 1.77 and 1.23 (clover), and 1.58 and 1.43 (grass). These values are less than those reported by others as being necessary for maximum clover production. Protein contents of pangolagrass samples taken in July, reflecting the previous clover growth, indicated that the all K treatments resulted in larger protein contents than the K-Na treatments. Either K or K-Na treatments, although not yielding more clover plus grass for a total of four harvests, did yield considerably more clover than did the rock potash treatments. Consequently, the quality of forage produced by K or K-Na treatments was higher, as well as the beef gain that could be expected from such a forage.

4. Emphasis was placed on the use of soil amendments that would result in soil Ca:Mg ratios that would more nearly approach the ratios as found in the forage. Soil ratios as a result of the application of various soil amendments, ranged from 20:1 for gypsum to 3:1 for dolomite, while clover and pangolagrass ratios ranged from 2:1 - 5:1 and 1:1 - 3:1, respectively.

5. Positive correlations existed between soil and tissue tests taken at the same time, for Mg, Na and particularly P. Positive correlations between the quantities of nutrients absorbed by clover and grass growing in mixtures were limited to K, P, S, and Mn.

6. Forage yields as a result of basic slag applications was superior to that produced by gypsum, by hydrated lime and gypsum, and by dolomite, hydrated lime, and gypsum for the first and second, third, and fourth harvests, respectively.

7. Cost estimates based on an initial five-year period indicated that over 1,000 pounds of ten cent beef per acre had to be produced during that time (above that quantity of beef produced on native pasture) to equal fertilizer expenses. It is believed that the necessary gains easily could be produced as a result of clover-grass pasture establishment and maintenance.

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BUSINESS MEETING

The regular Business Meeting of the Society followed immediately after the banquet on Friday evening at which the organization was privileged to entertain as its honored guests Provost and Mrs. J. Wayne Reitz, Dean and Mrs. C. V. Noble, Director and Mrs. Willard M. Fifield and Director and Mrs. H. G. Clayton.

Following the introduction of guests, President Gammon called for a brief report from the Secretary and Treasurer, particularly with respect to membership, publications and finances.

MEMBERSHIP

A summarization of the total membership of the Society as published in the Appendix and elsewhere in this volume may be of particular interest. It is as follows:

	Annual	*Sustaining*	*Total*
Florida	568	70	638
U. S.—other than Florida	204	41	245
Caribbean area including C. A., S. A., and Mexico	119	4	123
Foreign (other)	27	5	32
TOTAL	918	120	1038
Honorary Life Members			10
GRAND TOTAL			1048

PUBLICATION

With Proceedings Volume X published and Volume XI well on its way to press at the close of the official (calendar) year, the coming year offers full promise of a complete liquidation of the backlog of unpublished Proceedings. The Publication Committee for Volume XII, chairmanized by Dr. G. M. Volk, gave splendid help to the cause in their efficient and timely handling of this volume which has been in the hands of the membership for some time.

TREASURER'S REPORT

STATEMENT OF RECEIPTS AND DISBURSEMENTS
YEAR ENDING DECEMBER 31, 1953

CASH IN BANKS 1/1/53		
Everglades Federal Savings & Loan Assn.	$1,792.98	
Florida National Bank	7,293.91	$ 9,086.89
RECEIPTS		
Dues Collected and Proc. Sold	$1,938.80	
Dividend—Everglades Fed. Savings & Loan	36.18	1,974.98
Total Monies to Be Accounted for		$11,061.87

DISBURSEMENTS

Office Supplies	$ 114.20	
Postage	218.29	
Printing	1,879.62	
Payroll	820.00	
Bank Charges	.87	3,032.98

CASH IN BANKS

Everglades Federal Savings & Loan Assn.	$2,340.16	
Florida National Bank	5,688.73	8,028.89
Total Monies Accounted for		$11,061.87

NOTE: An amount of $366.06 to cover the expenses: Travel, entertainment, room rental and other facilities for meetings, phone calls, printing, etc. of the annual meeting in January 1954, is applicable to 1953 but will be reflected in the statement for 1954.

March 12, 1954

Soil Science Society of Florida
Belle Glade, Fla.
Gentlemen:

I have examined the cash on hand as of December 31, 1953, and the statement of Receipts and Disbursements ended on that date.

In my opinion the accompanying statement fairly presents the transactions during that period.

Yours very truly,
(Signed) W. C. Bamford
Certified Public Accountant

REPORT OF RESOLUTIONS COMMITTEE

A resolution was read proposing that Proceedings Volume XIII be dedicated to the memory of the late President of the University of Florida, Dr. J. Hillis Miller, and was unanimously approved.

A second resolution was read which told of the Society's loss by death of eight members during the year, among them the world famous microbiologist, Dr. S. N. Winogradsky, Pasteur Institute, Paris, France, one of our distinguished Life Members elected in 1950.

The president asked for a moment of silence following the reading of these resolutions. Both will be found published in full on pages 175 and 176 of this volume.

REPORT OF NOMINATING COMMITTEE

The Nominating Committee appointed during the morning meeting by President Gammon consisted of Dr. C. F. Eno, Chairman, and Drs. Henry Harris and Frederick Boyd. In making the nomination of the committee's choice Dr. Eno found many excellent reasons for recommending the name of Dr. Fred H. Hull, Head of the Department of Agronomy, to the position of Vice President and then moved the nominations be closed and the Secretary instructed to cast a unanimous ballot for their candidate. The Chair, receiving no further nominations for this position, asked for a vote on the committee's motion and it carried unanimously, there being no dissenting vote. By this action Dr. Ernest L. Spencer,

formerly vice president. antomatically became President of the Society and President Gammon took the place of Dr. I. L. Wander as a member of the Executive Committee.

President Spencer took the chair and, as a matter of new business. called on the Secretary to read a letter from the University of Florida Agronomists petitioning that a Crops Section be developed as a definite part of the Society, with or without a change of name in the organization in order to facilitate their participation in the meetings. This would follow quite closely the organization of the American Society of Agronomy with its two essentially separate sections covering the soil and crop sciences. respectively. In the discussion that followed. the very great advantages of such an affiliation were made very obvious. Dr. F. B. Smith closed the discussion with a motion to the effect that "we accept the petition of the University of Florda Agronomists to affiliate with the Soil Science Society of Florida and instruct the Executive Committee to work out the details of the affiliation with this group, including the formation of a Field Crops Section." This motion was seconded by Dr. G. M. Volk and carried unanimously.

Dr. Spencer then appointed a Publication Committee under the Chairmanship of Dr. Charles F. Eno, to assist with the preparation of the current Proceedings, Volume XIII, 1953, for the press.

There being no other business to come before the meeting, adjournment was declared at 10:30 P.M. after notice had been given by the Chair of a meeting of the Executive Committee on Saturday at noon immediately following the close of the regular program.

MEETING OF EXECUTIVE COMMITTEE

The noon meeting of the Executive Committee that was called by President Spencer, following the close of the regular morning session on Saturday, was the most complete and deliberate of any that has been held during the life of the Society.

In view of the fact that the position of Secretary-Treasurer in the Society is appointive and must be filled each year by action of the Committee, this was made the first item of business by requesting R. V. Allison of Belle Glade to continue in that post.

The petition of the University of Florida Agronomists relative to the formation of a Crops Section within the Society to be paralleled by a Soils Section also to be developed in such event, was discussed in some detail in accordance with the instructions of a motion that was made and unanimously approved at the time of the business meeting, when their letter was read. While no vote was taken on any phase of the question, the discussion was entirely favorable and, in fact, enthusiastic towards the idea in general though any change of name for the Society that would place a limitation of crops on the title was not looked upon with favor by the majority of the Committee. This was due particularly to the fact that it might be found feasible and desirable to have other subject matter sections set up in this same way covering other phases of closely related work such as forestry, horticulture, agricultural, engineering, etc., all with the view of more fully coordinating the broad ramifications of Soil Science with related fields of work. The change of name to Soil and

Plant Science Society was discussed and seemed to be the most favored if a change were to be made.

The question of holding Interim Meetings of a field nature some time during the Spring of each year at various points over the State was discussed most favorably and at length, with the result that it was decided to convert to such a purpose the Spring Meeting of the Agronomists that already had been planned. The tentative time that had been set for this was about mid-April. It was agreed that plans for such a meeting should be developed as rapidly as possible.

A question of increasing the annual dues from the present rate of one dollar per annum was discussed but no definite amount was suggested and no action was taken. As a modicum of recognition of the problem of ever-increasing prices for commodities and services needed to maintain the activity of the society, the Secretary was authorized to increase the price of the Proceedings to members and non-members alike, so long as there are any copies of a given volume available, from 50 cents to one dollar per copy.

The place and subject matter of the next Annual Meeting was discussed briefly. Though no definite action was taken, Winter Haven was favored and there was quite definite interest expressed in the idea that it might be possible to organize at least a preliminary symposium on tropical soils for December in cooperation with the regular meetings of the Caribbean Conference, even though of no more than a half a day in length.

The meeting was adjourned by the chairman at 1:30 P.M.

RESOLUTION OF SYMPATHY

Soil Science Society of Florida

WHEREAS, death has taken from our rolls during the year the following esteemed members of the Society whose sincere and constructive interest in all aspects of the work will make their absence keenly felt for a long time to come.

NOW, THEREFORE, BE IT RESOLVED, that this expression of sorrow over this great loss and of sympathy to the immediate families of the deceased be spread upon the records of this Society and a copy of same be sent to the closest member of the family of each.

COLLINS, W. O.
Athens, Ga.

HEARNE, W. E.
Washington, D. C.

MCCARTY, DAN
Ft. Pierce, Fla.

NYGARD, IVER J.
St. Paul, Minn.

PATTERSON, R. Y.
Clewiston, Fla.

PHELPS, EARLE B.
Gainesville, Fla.

THOMPSON, JAMES S.
Delray Beach, Fla.

WINOGRADSKY, SERGEI N.
Brie-Comte-Robert, France
(Honorary Life Member)

THE RESOLUTIONS COMMITTEE

LUTHER JONES, Chairman

RESOLUTION ON DEDICATION OF PROCEEDINGS

A Resolution Recommending the Dedication of Proceedings Volume XIII (1953) of The Soil Science Society of Florida to the Memory of Dr. J. Hillis Miller in Recognition of His Great and Enduring Services to the University in General and to the Basic Agricultural Sciences in Particular, Including Soil Science.

Whereas, the living being of the beloved president of the University, Dr. J. Hillis Miller in the ever deepening intensity and broadening usefulness of his activity in behalf of the University and of higher education in Florida and in the Nation, was so suddenly and so unexpectedly removed from an environment he loved so much and from a work he did so well, and

Whereas, he was so tireless in his efforts to build up the cultural life of the State and the physical well-being of its people by progressively improving the requisite physical and other means so obviously necessary to the accomplishment of those ends.

Now, Therefore, Be It Resolved, that Proceedings Volume XIII of our Society covering these current annual meetings for 1953 be dedicated to Doctor Miller as a token of our love and respect for him and as a small expression of our sincere appreciation for the great and good services he rendered the State of Florida; and

Be It Further Resolved, that this resolution be published in Volume XIII of the Proceedings and a copy of same sent to Mrs. Miller.

THE RESOLUTIONS COMMITTEE

Luther Jones, Chairman

NATHAN GAMMON, JR.

OFFICERS OF THE SOCIETY

1953—Retired

Nathan Gammon, Jr.	President
Earnest L. Spencer	Vice President
E. W. Wander	Member Executive Committee
R. V. Allison	Secretary-Treasurer

SOIL TESTING IN IRELAND

MICHAEL NEENAN *

Soil testing as a method of determining the manurial requirement of a crop has now become an established practice in most countries. As the methods used are largely empirical it is not surprising that different countries and even different Stations within a country have developed different systems of soil testing. However, since these methods must ultimately be correlated with field experiments, the variations from one Station to another make little difference to the farmer who ultimately uses the result.

MICHAEL NEENAN

Like many countries, Ireland has a soil testing system which is peculiar to itself though many of the analytical techniques are, of course, borrowed from those of other countries.

ADMINISTRATIVE PERSONNEL:

The soil testing service in Ireland is provided by the Department of Agriculture and the Agricultural Instructors who correspond with the County Agents of the U. S. These Instructors must possess, as a minimum qualification, the degree of Bachelor of Agricultural Science which is a four year course conducted by the National University of Ireland at their Dublin College. The funds from which these officers are paid are derived partly from local taxation on property and partly from a grant provided by the Department of Agriculture for that purpose. Each county has a number of Instructors depending on its requirements and its resources, but most counties average about five agricultural, two horticultural and three (female) poultry Instructors.

Each agricultural Instructor covers an area of approximately 150 square miles in which the number of farms would range from 2,000 to 2,500 depending on the locality. Along the western seaboard of the country where the farms are small and where agriculture is somewhat

* Assistant Soils Advisory Officer, Soil Laboratory Johnstown Castle, Agricultural College, Wexford, Irleand.

NOTE: Mr. Michael Neenan visited many Agricultural Experiment Stations in various parts of the United States early in 1953 but unfortunately could not be in Florida at the time of the meetings. However, he very kindly prepared for inclusion in the Appendix of Volume XIII the present discussion of the methods and procedures presently in use in Ireland to take care of a soil testing program that has developed very rapidly in his country during the past five years.—Ed.

difficult another group numbering 122 of non-degree officers assist in giving advice to farmers. These officers are directly responsible to the Department of Agriculture and administer certain special schemes for the benefit of the small land holders in the areas.

Another group of officers serviced by the soil laboratory are those of the Land Rehabilitation Project. This group bears some resemblance to the Soil Conservation Service of the U. S. but its activities are mainly in the realm of drainage and fertilization. The officers of this group, many of whom possess a degree in agriculture, have attended a short, intensive course in soil analysis interpretation. Refresher courses for all soil sampling officers are conducted annually at the Soil Laboratory.

The Soil Laboratory which was set up at its present location in 1948, is financed directly from government funds. The staff at present consists of nine agricultural graduate officers, three chemists, thirty-three laboratory assistants, ten laboratory attendants and five of a clerical staff. The laboratory assistants also assist with some of the investigational and research work during the off season.

SOIL TESTING PROCEDURE

(1) Sampling:

It is recognized that proper sampling is fundamental to any system of soil testing. Consequently, samples are never accepted from farmers directly, all samples being taken by the various categories of officers mentioned above. Even with such a rigid procedure, it is felt that the main variations which do occur in soil testing are those due to poor sampling.

The system of sampling which these officers follow is that of segregating the area into uniform sampling areas. This can readily be done in the field either by preliminary soil survey with the auger or by a rapid pH check by means of indicators. In this way uniform areas are recognized and sampled accordingly, allowance also being made for previous treatments. If, however, the field is more than five statute acres in extent although uniform, a separate sample is taken for every five acres or part thereof. The sampling by the Instructor has the additional advantage that it enables other possibilities of crop failure such as insect pests or fungus diseases to be eliminated before having recourse to soil analysis.

The tools used in sampling are either an ordinary wood auger (½" diameter) or a metal tube rather similar to that described by Volk and Peech (1).[1]

Each composite sample is drawn from at least 20 sub-samples. Where fertilizers have been recently applied, samples are taken 0 - 1" and 1 - 6", otherwise samples are 0 - 6" and 6" to subsurface.

The samples are then put into lined kraft bags approximately 9" x 5" for dispatch to the laboratory. Samples are forwarded in large wooden boxes which have either fifty or one hundred separate compartments. The Instructor provides the laboratory with one key of the box, while he retains the other.

Accompanying each sample is a form on which is recorded all the data required. The forms are duplicated, one copy going to the labora-

[1] Numbers so used in the text have referred to Literature Cited.

SOIL SAMPLES FOR ANALYSIS

FIELD NOTES:

Name and Address of Farmer .....

Date of Sampling .....

Name or No. of Field .....

Area sampled in Acres .....

No. of Samples .....

Identification No. (s) .....

Laboratory No. (s) .....

SOIL DESCRIPTION:

Situation	
Geological Origin	
Depth	
Colour	
Texture and Structure	
Drainage	
Root Development	
Other Observations	

PREVIOUS TREATMENT, CROPPING DATA, ETC.

Year	19	19	19	19	19
Crop					
Crop Response					
Manurial Treatment and Liming					
Other Observations					

Signature of Instructor.....

Figure 1. Standard form for recording sample descriptions and analytical results.

tory and one being retained by the Instructor. A copy of the form is shown in Fig. 1. It is proposed in the near future to replace the form by a standard card which can be used in a card index system.

(2) Preparation of Samples:

On arrival at the Laboratory, samples are given a Laboratory number and dried in a specially designed room at a temperature not exceeding 35° C. Drying, however, is only necessary during the winter months. Having been dried, the samples next go to the sieving machine, where the soil is crushed, stones, roots, etc. being removed. The output is approximately fifty samples per hour. A note on the design of the ma chine is given as a footnote at the end of this discussion.

After sieving, the samples are arranged in batches of 100 and conveyed to the extraction room. After the analysis is completed, the soils are stored for one month before being finally discarded.

(3) Extraction:

The extracting solution used is Morgan's which has been found generally satisfactory for most elements (2). In certain circumstances, however, a more drastic extractant, Bray's ammonium fluoride-hydrochloric acid has been used for less readily available phosphates (3). In testing for boron, however, soils are extracted with hot water in accordance with the method of Haas (4), while in testing for molybdenum, Davies and Griggs (5) ammonium oxalate—oxalic acid solution has been used with considerable success.

In extracting for the major elements with Morgan's extractant, 6 grams of soil are shaken for 30 minutes with 30 ml. of the solution. The extracts are then filtered into filtering units (combined test-tube and funnel) using a No. 2 Whatman (fast) filter paper. Both the extracting bottles and filtering units are permanently mounted in racks of 10 which facilitates handling. In the course of shaking the one hundred samples are placed in two tiers of 50 and stoppered by a large "Dunlopillo" rubber sponge covered by a sheet of plastic.

(4) Analytical Procedure:

Aliquots for analysis are removed from the filtering units by means of ordinary medical syringes which have previously been accurately calibrated for this purpose.

Phosphate and Calcium are determined as described by Peech and English (6) except that molybdenum blue color is read on an EEL colorimeter rather than visually. Potassium is read on a Lange flame photometer using an external galvanometer and correcting for calcium when this goes above 500 ppm. This gives a sensitivity of about 1 ppm which is about twenty-five times more sensitive than the turbidimetric method. Some soils have been encountered which gave values of as low as 5 lbs. per acre of K which would have been regarded as in the region of 50 lbs. per acre by the method of Peech and English (6).

The pH is determined on 1:1 soil water suspension using a glass electrode pH meter. Several makes of pH meters have been used including Beckman, Cambridge, Muirhead and Doran (Danish). The battery models have been found more generally reliable than mains operated instruments. In pH determinations samples are also handled on a batch basis. 10 one hundred ml. beakers being mounted on each rack. A

TABLE 1.—Tentative Limit Values (Lbs./Acre).

Limit Value	Value	Calcium	Phosphorus	Potash	Nitrate Nitrogen	Magnesium	Iron	Manganese	Aluminum
Extra Low	1	0 - 400	0 - ½	0 - 40	0 - 5	0 - 10	0 - 5	0 - 25	0 - 10
Very Low	2	400 - 800	1 - 3	41 - 80	5 - 10	10 - 25	5 - 10	25 - 50	10 - 25
Low	3	800 - 1200	4 - 5	81 - 120	10 - 15	25 - 50	10 - 15	50 - 75	25 - 50
Low to Medium	4	1200 - 1600	6 - 9	121 - 160	15 - 20	50 - 100	15 - 20	75 - 100	50 - 100
Medium	5	1600 - 2000	10 - 20	161 - 200	20 - 30	100 - 150	20 - 30	100 - 150	100 - 150
Medium High	6	2000 - 3000	21 - 40	201 - 250	30 - 40	150 - 200	30 - 40	150 - 200	150 - 200
High	7	3000 - 5000	41 - 60	251 - 350	40 - 60	200 - 250	40 - 50	200 - 250	200 - 250
Very High	8	5000 - 9000	61 - 85	Over 350	60 - 100	250 - 500	50 - 100	250 - 350	250 - 500
Extra High	9	Above 9000	Over 85		Over 100	Over 500	Over 100	Over 350	Over 500

home-made, foot-operated device enables the electrode to be washed down between each successive reading.

The limit values used for the major elements are based on those of Peech et al (6) modified in the light of subsequent finding, to suit Irish conditions.

The results are forwarded to the Instructors expressed either in lbs. per acre (in the case of experimental samples) or more usually as numeral limit values. Table 1 gives the scale of values and their corresponding limit values.

The average delay from the time of receipt of samples until the sending out of the result, is ten days. There is, however, a strong seasonal fluctuation in the receipt of samples as shown in Fig. 2. It will be observed that the greatest influx of samples occurs in the spring of the year corresponding with the sowing time of cereals, root crops and potatoes. By agreement with other branches of the Department of Agriculture, however, it has been arranged that samples not intended for advisory purposes in connection with arable crops, should come in at the off-season of the year. In this way it is possible to provide all the year round work for the entire staff with little overtime work even at the peak season.

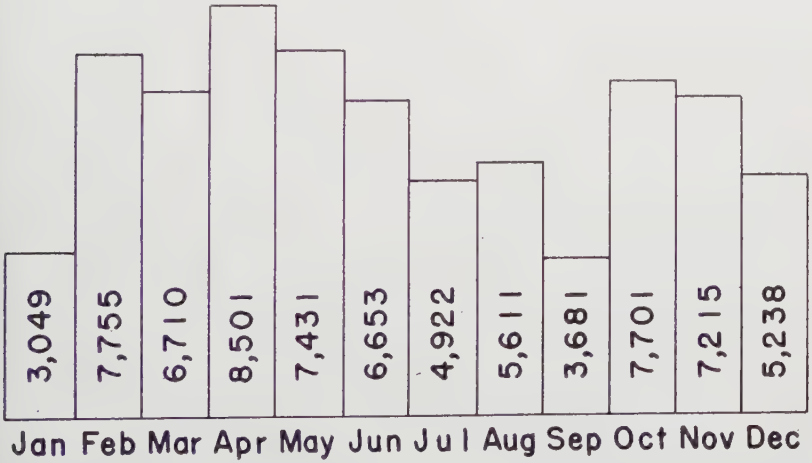

Figure 2. Periodicity in the inflow of samples — 1953.

(5) Methods of Analysis Used in Special Investigations:

County Instructors and other advisory officers throughout the country frequently seek the aid of the Laboratory in ascertaining the cause of crop failures and livestock disorders arising from soil conditions. Such problems often call for a micronutrient or other non-routine analysis on soils or plants. At present both chemical and microbiological methods are used for micronutrient assay. Except where otherwise stated, tissue analysis is in accordance with the methods of Piper (7).

Magnesium: Since the original titan yellow method of Peech and English (6) was subject to many serious interferences, a number of other methods have been investigated. At present the method used on

soils and tissues is that of Hunter (8) but investigations are still in progress.

Manganese: Methods for this element in soils are also under investigations and to date a number of methods have been used viz. periodate and formaldoxime using Morgan's extracting solution (2). Neither of the methods are entirely satisfactory for the detection of manganese deficiency, but as the availability of manganese is a function of a great many factors other than the manganese concentration of the soil solution, chemical tests for this element when present in low concentration are of limited value. The formaldoxime method used in conjunction with Morgan's extractant (2), however, has proved reasonably satisfactory for the diagnosis of manganese toxicity in soils. Analysis for manganese on tissues is by the dry ashing procedure of the A.O.A.C. (9).

Nitrogen: Total Nitrogen on soils and tissues is determined by the microdiffusion method of Conway as modified by McDonnell and Murphy (10). The method which is both rapid and accurate has proved of considerable value in detecting nitrogen deficiency.

Aluminum: Tests for this element have been useful in assessing the lime requirement of different soils. It has been found that in some soils, high in aluminum (up to 700 lbs./acre using Morgan's extractant) that the lime requirement was more nearly a function of the level of aluminum than of the pH of the soil. The test used for this element is that of Peech and English (6).

Boron: As already mentioned, soils are tested for this element where it is considered necessary. On acid soils the critical level has been found in agreement with the findings of other workers to be in the region of 0.35 ppm, while on alkaline soils, boron deficiency has occurred at levels up to 0.75 ppm of water soluble boron.

Molybdenum: Since molybdenum deficiency in crops and molybdenum toxicity in animals both occur in Ireland, tests for this element have received considerable attention. Micro-biological tests, using Aspergillus niger, were found rather difficult to reproduce, while analysis for total Mo gave poor co-relation with field responses. The most satisfactory test for this element was found to be that of Davis and Griggs (5) mentioned above. Using this method, the critical level for deficiency was found to be in the region of 0.14 ppm while soils in which the vegetation was toxic usually gave values in excess of 0.30 ppm. Molybdenum determination in tissues is carried out by the recent method of Piper and Beckwith (11), in which di-thiol is the essential reagent.

Cobalt: As cobalt deficiency occurs rather widely in the sheep farming districts of the country, tests for this element are in fairly constant demand. The method used is that of Askew and Kitson (12) in which the extractant is 6N HCl. Cobalt deficiency in many of these areas is rather similar to that which was first reported from Florida in that total cobalt is frequently below 2 ppm. Close correlations have been observed therefore between the incidence of pining and the total cobalt content of the soil.

Tests for Concrete Tiles: In connection with land reclamation, it has been found that, on some acid soils, severe corrosion of concrete drain pipes occurs. One of the factors concerned in this corrosion is the pres-

ence of high concentrations of sulphides in the soil. Consequently prior to the planning of any major drainage operation, soil samples are submitted to the laboratory to ascertain the suitability or otherwise of concrete pipes for the particular situation. (Owing to the rather high cost of clay pipes in Ireland, concrete pipes must be used whenever possible).

Tests are carried out for sulphates, exchangeable hydrogen and exchangeable acidity. On the results of these analyses it is possible to predict the ability or otherwise of a soil to corrode concrete pipes.

Selenium: Since an occurrence of selenium toxicity in the country from Co. Limerick in 1950, it has been necessary to make occasional checks for this element in other parts of the country. The method of analysis, which is that of Robinson (13), is for total selenium in the soil.

Other Elements: Tests for many other elements are carried out either colorimetrically by means of a DU Beckman photometer or spectrographically by means of a Hilger large quartz spectograph.

The soils having been tested, the results in lbs./ac. or test values are returned to the Instructor, and not to the farmer as in the case of some other European countries. The interpretation of the tests was originally done by the specialists of the extension staff, but as more experience was built up, and as the volume of work in this regard became progressively greater, the interpretation of the results was turned over to the Instructors. These officers were given an initial short but extensive course in the subject and afterwards provided with the necessary modifications as more information became available. This system has many advantages particularly in a country where a great variety of crops are grown. It might happen on occasions that a farmer had his soil sampled intending to sow, say wheat, but later changed his mind and decided to sow sugar beet. If the recommendations are made at the Soil Laboratory, the disadvantages of this system are obvious. Another advantage of the recommendations being made locally is that it enables the Instructors to make adjustments for the economic position of the farmer which varies appreciably in different parts of the country.

Fertilizer Recommendations:

There is available in the country a considerable volume of information on crop response to nutrient status of the soil almost all of which is based on Morgan's extractant. In obtaining this information recourse was had to pot experiments, and field experiments on a wide variety of soil types. Much of this information is still unpublished, but the following Table 2 gives the quantities of fertilizer which have been found most economical to apply to the various crops at the different nutrient levels.

These dressings of fertilizer are for a modal soil which, in the case of phosphate, is defined as a correctly limed, medium loam in a district of average rainfall (about 40" annually). For potash, the modal soil is a non-limestone or partly-limestone derived, medium loam of average organic matter content and having a calcium status of 3000 - 4000 lbs./acre.

Corrections for Phosphate:

For a clay loam, increase by 12½%.
For a light loam, decrease by 15%.

TABLE 2.—Quantity of P_2O_5 and K_2O to Apply at Different Test Values (Lbs. per Acre) Also Nitrogen.

PHOSPHATE

P Value Test		Cereals	Potatoes	Mangels	Swedes	Kale	Sugar Beet	Clovers		Grasses	Pastures	Meadow
	Lbs. of P per Acre							Red	White			
1	0 - ½	40	96	80	96	88	83	64	56	56	48	56
2	1 - 3	32	80	64	80	64	80	56	40	40	40	48
3	4 - 5	24 - 16	64	48	64	48	56	40	24	24	24	32
4	6 - 9	16 - 18	48	32	48	32	40	24	16	16	16	16
5	10 - 20	....	32	16	24	16	24	16	8	8	....	....
6	21 - 40	....	24	....	....	....	16	....	....	....	..	..
7	41 - 60	....	....	....	....	....	....	....	....	....	....	

K Value Test		POTASH										
	Lbs. of K per Acre											
1	0 - 40	60	170	120	120	120	120	100	90	80	90	90
2	41 - 80	40	150	90	100	100	100	90	75	60	75	75
3	81 - 120	20	120	75	75	90	90	60	50	40	50	50
4	121 - 160	....	90	50	50	60	60	30	30	....	....	....
5	161 - 200	....	60	25	25	30	40	....	....	....	..	..
6	201 - 250	....	30	....	....	....	30	....	....	....	..	..
7	251 - 350	....	....	....	....	....	....	....	....	..	..	..
8	Over 350	....	....	....	....	....	....	....	....	..	..	..

Nitrogen												
Lbs. N per Acre		22 - 44	50 - 70	55	50	66	66	....	..	44	33	33

For a soil of non-calcareous parent material, below ph 5.5 irrespective of whether or not liming is to be carried out, increase by 12½%. Some eleven other corrections are made in reaching the final figure.

Corrections for Potash:

The corrections in respect to potash are based mainly on the level of calcium and percentage clay in the soil. For every 2,000 lbs. in excess of 4,000 of readily available calcium per acre, potash is increased by 10% subject to a maximum of 40%.

For heavy textured clay loam and clay soils increase by 10% and 15% respectively.

Where conditions are poor, increase by 15%. In all seventeen corrections are made for potash.

TABLE 3.—Lime Treatment for Organic and Mineral Soils in Relation to the Existing Reaction (pH) Value.

ORGANIC SOILS

Calcium Values	pH Values				
	4.0	4.4	4.8	5.0	5.5
	Rate in Tons/Acre				
1	6.5	6.5			
2	6.0	6.0	5.0		
3	5.5	5.5	4.0		
4	5.0	4.5	3.5	3.0	
5	4.5	3.5	3.0	2.5	2.5
6					
7	4.0	3.0	2.0	2.0	1.5
8					
9	3.0	2.5	1.5	1.0	

MINERAL SOILS

Calcium Values	pH Values								
	4.4	4.7	5.0	5.2	5.5	5.8	6.0	6.2	6.5
	Rate in Tons/Acre								
1	5½	5	4½						
2	5	4½	4	3¾					
3	4½	4	3¾	3½	3¼	3			
4			3½	3	2¾	2½	2¼		
5			3	2¾	2½	1¾	1½		
6					2¼	1½	1¼	1	
7					2	1¼	1	¾	
8					1½	1	¾	½	
9					1	¾	½		

Recommendations for Lime:

The quantities of ground limestone recommended are given in Table 3. Here the table is divided into two parts one for organic and one for inorganic soils. The modal inorganic soil here is a medium loam of

low organic matter content of base exchange capacity of 10 - 20 milli-equivalents per 100 grams of soil.

Corrections for Lime:

The main corrections for lime are as follows:

Texture: The rate of application which is decreased by ½ ton per acre for light loams, 1 ton per acre for sandy loams and 1½ - 2 tons per acre for loamy sands. On the heavier textured soils, the rate is increased by ½ ton per acre for heavy loams, ½ to 1 ton for clay loams and 1 - 2 tons per acre for clays.

In areas of high rainfall increase by 20% and in some limited areas of low rainfall, decrease by 20%.

Until more definite information is available, lime is not recommended for peaty soils above pH 5.0.

These recommendations, which are provisional, are revised at an annual meeting of the Instructors, as more information becomes available.

Other Elements:

In the case of minor element deficiencies, general recommendations are not given. This is necessary because, as a result of difficulties between soil types and phases, each case must be treated as a separate problem.

Response to the Scheme:

Although soil testing has been used in the country as far back as 1944, it was not until 1948 that any large numbers of samples were received. This was partly as a result of the many deficiencies which had sprung up during the war years when fertilizers were unobtainable, and partly

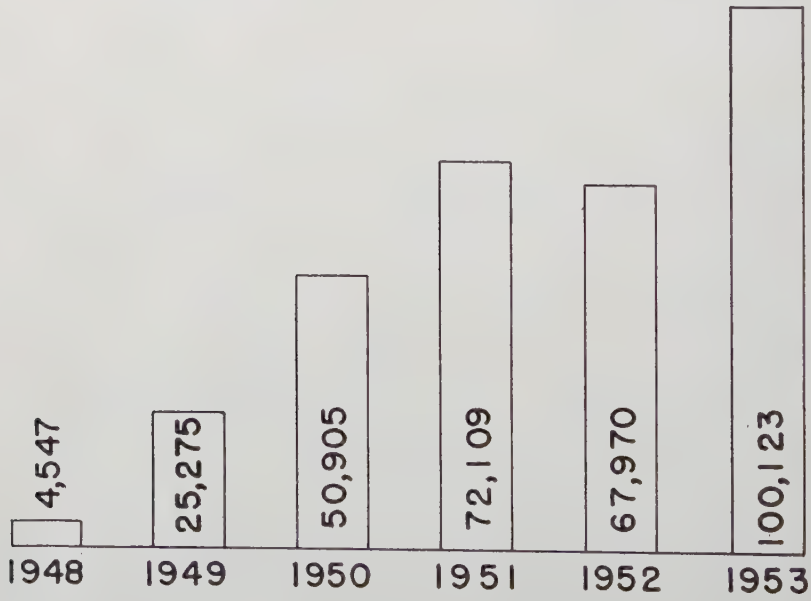

Figure 3. Record of soil samples tested for years 1948 - 1953.

also due to the growing consciousness of farmers of the value of agricultural research. Indeed so rapid has been the expansion of soil testing, that difficulty is experienced in recruiting staff to keep pace with the work which continues to increase substantially each year. The rate at which soil testing has grown in Ireland during recent years, as shown in Fig. 3, is an indication that farmers have found soil testing satisfactory in diagnosing the various mineral deficiencies of plants and animals.

A survey made of the nutrient status of the country in 1950 revealed that some 75% of the soils were to some extent deficient in lime, some 90% in phosphates and more than 80% deficient in potash. In addition, many unusual and interesting soil problems have been discovered, amongst which are selenium toxicity in animals, cobalt deficiency in sheep, molybdenum toxicity in livestock as well as molybdenum deficiency in the brassicas. While these represent the more spectacular problems which have been solved by soil analysis they are insigificant by comparison with what has been achieved in providing a sound basis for the application of lime, phosphate, potash and nitrogen.

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Notes on the Sieving Machine:

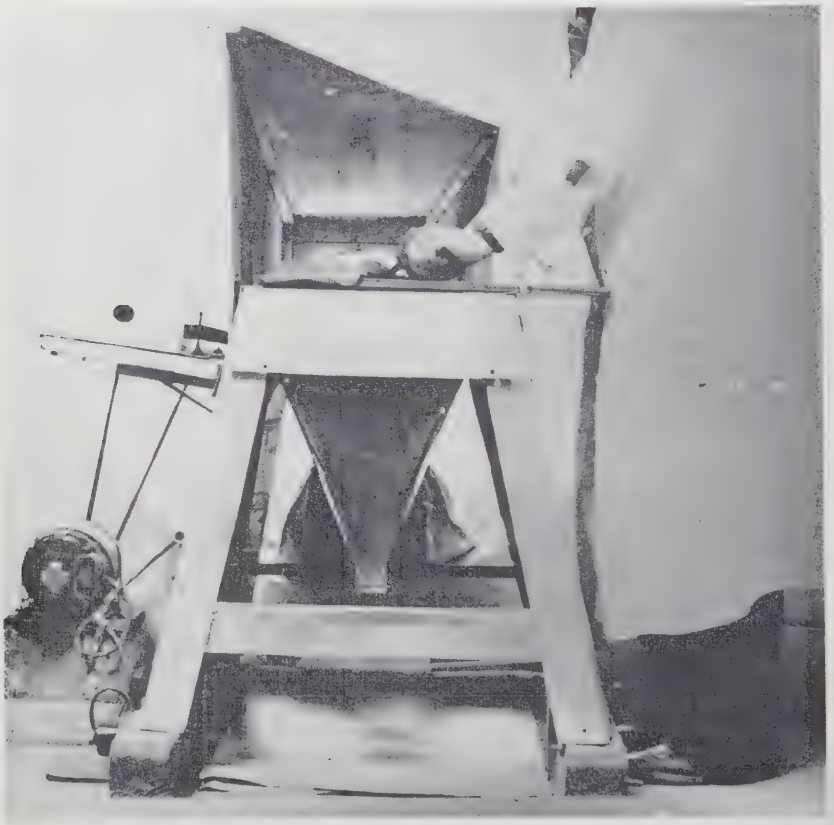
This machine was developed at the laboratory with two objectives in view:

(a) To speed up the work of sieving, which was initially done by hand, and was consequently a tidious, time-consuming job.

(b) To overcome the problem of dust during sieving operations.

The machine consists of a square, 12″, 2 mm. sieve sloped at an angle of 20° and mounted in the top of a sheet metal (copper) funnel which is suspended inside an angle-iron framework. The combined funnel and sieve are given a reciprocating (1″ stroke) motion by a camshaft driven by a ¼h.p. motor mounted at one side of the machine. Over the sieve

and resting on top of the framework is a rectangular sheet-steel tray, on which the sample is crushed with a wooden, metal-covered, hand-operated, roller. After crushing, the sample is brushed by hand through a slot in the tray into the sieve.



General view of sieving machine described in present article showing limited detail of its operation.

Dust is carried out into the open air by a 9″ ventilator fan mounted in a suitable window or wall opening at the back of the machine. A plywood duct runs from the fan to the top of the machine, which it partly covers. Two operators are required: one pours the sample on to the tray, hands the bag to the other operator, and crushes the sample. The other operator places the bag underneath the funnel, brushes the crushed soil into the sieve through the slot in the tray, and removes the bag when sieving has been completed. The coarse material runs off the sloped sieve into a canvas collecting bag attached to the rear. The machine has completely eliminated dust and enables sieving of soil samples to be carried out with a minimum of delay and labour.

Tests have shown that there is no contamination caused to samples from samples previously passed through the apparatus.

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